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Altimeter Processing Tools for Analyzing Mesoscale Ocean Features

by

Michael J. Caruso, Ziv Sirkes, Pierre J. Flament, and M.K. Baker

September 1990

Technical Report

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Abstract

Satellite altimeters provide many opportunities for oceanographers to supplement their research with a valuable new data set. The recent GEOSAT exact repeat mission is the first of several altimetry missions proposed during the next decade. To utilize this new data, a software package was developed at the Woods Hole Oceanographic Institution and the University of Hawaii to facilitate the extraction of useful information from the NODC distributed GEOSAT data tapes. This software package was written with portability and modularity in mind. It should be possible to use this package with little or no modifications on data from future altimeters. The code was written in C and tested on Sun workstations and is oriented toward UNIX operating systems. However, since standard code was used, the programs should port easily to other computer systems. The modularity of the code should enable users to create addition programs. Additional programs designed to handle collocated water vapor corrections are also included for comparison.



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Altimeter Processing Tools for Analyzing Mesoscale Ocean Features

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1 Introduction

The altimeter is an active microwave radar that measures the distance between itself and the ocean surface. A pulse of known power and duration is directed toward the sea surface. By measuring the power of the return pulse, it is possible to determine the altimeter height. By fitting the shape of the return pulse, it is possible to calculate the significant wave height and the near-surface wind speed. The uses of satellite altimetry include the determination of ocean currents, measurement of significant wave height and ocean tides as well as estimation of surface wind speeds.

The U.S. Navy altimeter satellite GEOSAT (GEOdetic SATellite) was designed to provide the U.S. military with a highly improved marine geoid. In October 1986, when the satellite had completed this classified work, it was moved into a 17-day exact repeat orbit. The new orbital parameters corresponded to the 1978 Seasat mission. This new unclassified orbit was corrected periodically to provide a groundtrack repeatability to within 1 km.

The primary purpose of this project is to perform a "repeat" or "collinear" track analysis. This analysis requires sorting the data into collinear tracks, correcting the sea surface heights for various measurement errors and regridding the along-track data to a common grid. We developed generalized programs to read and assimilate the data into a usable data set. These programs were developed on a Sun Workstation¹, but could be easily ported to other computer systems.

Since GEOSAT does not have an onboard sensor to measure the effects of water vapor, two separate estimated water vapor corrections are supplied with the data. One alternative used here is the first Special Sensor Microwave/Imager (SSM/I), launched in June 1987 aboard a Defense Meteorological Satellite Program spacecraft. The SSM/I senses brightness temperatures. From those brightness temperatures environmental parameters such as wind speed and water vapor can be derived (Hollinger et al. 1987).

We decided to write several simple programs to read in the binary data tapes, format the data and write out the ASCII equivalents. We also worked out a naming convention to facilitate the storage and retrieval of individual subtracks. Programs were also written for repeat track analysis and to interpolate the data to a uniform latitude/longitude grid. These programs were designed with mesoscale motions in mind. However, since the programs are modular, users can easily use their own orbit and geoid corrections to study basin scale problems. We left programs that interpret the data for implementation by the individual users.

Section 2 describes the GEOSAT geophysical data record (GDR) and section 3 describes the SSM/I data record. Section 4 illustrates the approach to handling the expansive data set and section 5 describes the programs and subroutines developed to handle the GEOSAT data along with explanations of input and output data. Section 6 describes the use of these programs to perform a repeat track analysis of a section of the North Atlantic from 22° N to 48° N and 284° E to 316° E. The appendices contain UNIX²-style manual pages, program and subroutine listings and UNIX shell scripts described throughout the text.

¹Sun Workstation is a registered trademark of Sun Microsystems, Inc.

²UNIX is a trademark of AT&T Bell Laboratories

2 Geophysical Data Record GDR

The raw altimeter data are collected at the Johns Hopkins University Applied Physics Laboratory (JHU/APL) and are processed by the National Oceanographic and Atmospheric Administration (NOAA). The data are merged with ephemerides and corrections are added for tides and refractions (Cheney et al. 1987.) The National Ocean Data Center (NODC) in Washington, D.C. distributes the user handbook (Cheney et al. 1987) and the completed GDR which is available on tape.

Table 1 shows the parameters contained in each GDR. The parameter column contains the names used in the user handbook and the abbreviation column contains the names used for each parameter in the programs and in the text.

The first 5 items are stored as 4-byte integers. Parameters *utc* and *utcm* contain the time of the record since the 00:00 UTC, 1 Jan. 1985. The time of the record may be calculated by $t = utc + utcm * 10^{-6}$. The parameters *Lat* and *Lon* contain the latitude and longitude in microdegrees. A positive latitude is north of the equator and the longitude is measured east of the Greenwich meridian. The satellite orbit height, *Orb*, is given in mm above the reference ellipsoid.

The next 29 parameters are stored as 2-byte integers. The first of these parameters, *m_h*, is the average sea surface height of the record given in cm above the ellipsoid. The standard deviation of the heights used to calculate *m_h* is *s_h*. The height of the geoid above the ellipsoid in cm is *Geoid*. The measured 10-per-second sea surface heights used to calculate *m_h* are *h[1]-h[10]*. The average significant wave height in cm is *swh* and *s_swh* is the standard deviation of the measurements used to determine *swh*. The backscatter coefficient, *s_naught* is computed aboard the spacecraft in 0.01 dB. The automatic gain control, *agc*, is also determined aboard the spacecraft and *s_agc* is the standard deviation of the measurements used to determine *agc*. The height offset used for all measurements over land is *h_off*. The correction to *m_h* for the solid earth tide is *sol_tide* and the correction to *m_h* for the ocean tide is *oc_tide*. The correction to *m_h* to account for the time delay caused by water vapor in the troposphere, *wet_fnoc*, is derived from the Fleet Numerical Oceanographic Center (FNOC) NOGAPS model. An alternative correction for the water vapor is given as *wet_smmr*. The correction for the dry troposphere is given as *dry_fnoc*. A correction for the altimeter time delay due to molecules in the troposphere is given by *dry_fnoc*, which is also calculated from the FNOC NOGAPS model. The correction resulting from free electrons in the ionosphere is given by *iono_gps*. Two corrections are also given for height bias. The correction *dh_swh* is from a combination of significant wave height and attitude bias and *dh_fm* is due to compression of the altimeter pulse. The final parameter, *att* is the off-nadir satellite orientation angle. See the GEOSAT Altimeter GDR User Handbook (Cheney et al. 1987) for more information and references for these parameters.

3 SSMI Data Record

The raw SSMI data were collocated with the GEOSAT subtrack by Wentz [1989]. The collocated SSMI data records are at 10 second intervals and consist of 12 bytes as described in table 2. A wind speed value of 45 denotes no wind data available due to rain and a columnar water vapor value of 10 denotes no vapor data available due to rain.

| Geophysical Data Record Contents | | | | | |
|----------------------------------|-----------------------------|--------------|---------------|----------------------|-------|
| Item | Parameter | Abbreviation | Units | Range | Bytes |
| 1 | UTC | utc | Seconds | 0 to 2 ³¹ | 4 |
| 2 | UTC(cont'd) | utcm | Micro Second | 0 to 1E6 | 4 |
| 3 | Latitude | lat | Micro Degrees | +/- 7.21E7 | 4 |
| 4 | Longitude | lon | Micro Degrees | 0 to 360E8 | 4 |
| 5 | Orbit | orb | Millimeter | 7E8 to 9E8 | 4 |
| 6 | H | m_h | Centimeter | +/- 32766 | 2 |
| 7 | Sigma_H(σ_H) | s_h | Centimeter | 0 to 32766 | 2 |
| 8 | Geoid | geoid | Centimeter | +/- 1.5E5 | 2 |
| 9 | H(1) | h[1] | Centimeter | +/- 32766 | 2 |
| 10 | H(2) | h[2] | Centimeter | +/- 32766 | 2 |
| 11 | H(3) | h[3] | Centimeter | +/- 32766 | 2 |
| 12 | H(4) | h[4] | Centimeter | +/- 32766 | 2 |
| 13 | H(5) | h[5] | Centimeter | +/- 32766 | 2 |
| 14 | H(6) | h[6] | Centimeter | +/- 32766 | 2 |
| 15 | H(7) | h[7] | Centimeter | +/- 32766 | 2 |
| 16 | H(8) | h[8] | Centimeter | +/- 32766 | 2 |
| 17 | H(9) | h[9] | Centimeter | +/- 32766 | 2 |
| 18 | H(10) | h[10] | Centimeter | +/- 32766 | 2 |
| 19 | SWH | swh | Centimeter | 0 to 2E3 | 2 |
| 20 | Sigma_SWH(σ_{swh}) | s_swh | Centimeter | 0 to 2E3 | 2 |
| 21 | Sigma_naught(σ_o) | s_naught | 0.01 dB | 0 to 6.4E3 | 2 |
| 22 | AGC | agc | 0.01 dB | 0 to 6.4E3 | 2 |
| 23 | Sigma-AGC(σ_{AGC}) | s_agc | 0.01 dB | 0 to 6.4E3 | 2 |
| 24 | Flags | | | | 2 |
| 25 | H Offset | h_off | Meters | 0 to 5.4E4 | 2 |
| 26 | Solid Tide | sol_tide | Millimeter | +/- 1000 | 2 |
| 27 | Ocean Tide | oc_tide | Millimeter | +/- 10000 | 2 |
| 28 | Wet (FNOC) | wet_fnoc | Millimeter | 0 to -1000 | 2 |
| 29 | Wet (SMMR) | wet_smmr | Millimeter | 0 to -1000 | 2 |
| 30 | Dry (FNOC) | dry_fnoc | Millimeter | -2000 to -3000 | 2 |
| 31 | Iono (GPS) | iono_gps | Millimeter | 0 to -500 | 2 |
| 32 | dh (SWH/ATT) | dh_swh | Millimeter | +/- 9999 | 2 |
| 33 | dh (FM) | dh_fm | Millimeter | +/- 999 | 2 |
| 34 | Attitude | att | 0.01 Degree | 0 to 200 | 2 |

Table 1:

| SSMI Data Record Contents | | | | |
|---------------------------|--------------|---------|----------------------|-------|
| Item | Parameter | Units | Range | Bytes |
| 1 | Time | Seconds | 0 to 2 ³¹ | 4 |
| 2 | Latitude | Degrees | - | 2 |
| 3 | Longitude | Degrees | - | 2 |
| 4 | Encoded Data | - | See table 3 | 4 |

Table 2:

| SSMI encoded data description | | | | |
|-------------------------------|----------------------------|--------------|--------|--|
| Item | Parameter | Abbreviation | Range | Units |
| 1 | Data flag | fl | 0 to 3 | 0 - Over ocean 1 - No orbit altitude information 2 - Over land 3 - Over sea ice |
| 2 | Wind speed | ws | - | ms^{-1} |
| 3 | Columnar water vapor | vp | - | $gr \cdot cm^{-2}$ |
| 4 | Columnar cloud water vapor | cl | - | $gr \cdot cm^{-2}$ |
| 5 | Rain rate | rn | - | $mm \cdot hr^{-1}$ |

Table 3:

4 Data Handling

In this text, the data received from NODC is referred to as "raw" and should not be confused with the data received directly from the satellite JHU/APL. Each data tape contains approximately 34 days of data for a total of more than 120 Megabytes so that it is impractical to keep all available data on disk.

Since these programs were developed to analyze mesoscale features, the data is split from the raw sequential input data into regional areas. The repeat analysis required developing an orbit numbering scheme to identify collinear orbits. This scheme separates the GDRs into ascending and descending orbit segments starting and ending at the most northern and most southern point of an orbit. An orbit is defined to be the combination of the ascending and descending segments beginning with the descending segment. A segment is defined as any part of a complete orbit. These orbits were numbered from 0 to 243 with zero being the first orbit on the first NODC data tape. Since the orbits repeat every 17.05 days, the orbits were also named by the repeat cycle from which they were extracted. A repeat cycle is defined as the combination of all orbits beginning with 0 and ending with 243. The cycles are also numbered consecutively starting with zero.

The resulting files are named *cmmm.dnnn* for descending orbit *nnn* and *cmmm.annn* for ascending orbit *nnn* from repeat cycle *mmm*. Table 4 shows the naming conventions used in this report for the various files created during analysis.

| Naming conventions | | |
|----------------------|---------------|---|
| Convention | Example | Description |
| <i>cmmm.annn</i> | c002.a088 | Raw GEOSAT binary files |
| <i>cmmm.annnc</i> | c002.a088c | Cleaned and corrected GEOSAT binary files |
| <i>cmmm.annncs</i> | c002.a088cs | Cleaned, corrected and regridded GEOSAT binary files |
| <i>cmmm.annncs_r</i> | c002.a088cs_r | Residuals from repeat analysis, ASCII format |
| <i>annncs_m</i> | a088cs_m | Mean and variability for repeat analysis, ASCII format |
| <i>cmm.annnasc</i> | c002.a088asc | ASCII file containing extracted data |

Table 4:

One alternative orbit numbering method is based on the longitude where the orbit crosses the equator. This method, however, does not convey the order of each or-

bit in time. Orbit c010.a045 passes the Gulf Stream approximately three days before c010.a088. Knowing the equatorial crossing of an orbit segment can be useful in quickly locating an orbit in space relative to another orbit or for comparing results with other numbering methods. A program was written to convert the sequential numbering to the equatorial numbering.

5 Programs and Subroutines

This section contains descriptions of programs and subroutines used to analyze GEOSAT data. In the examples given, the UNIX prompt is represented by a percent sign "%".

Most programs were designed to read and write the standard 78-byte GEOSAT GDR so that the output from one program may be used as the input for another. Programs are also simple and single-purpose. Instead of a program that removes spurious data points and applies orbit corrections, one program is used to apply the corrections and one program is used to remove unwanted data. This allows quick code modifications and substitutions. An alternative program to compute orbit corrections can be directly substituted for the supplied correction program. A single multi-purpose program would require major modifications to implement the new corrections.

Several programs were designed to read or write ASCII data for use with existing plotting packages and display programs. ASCII data allows users to choose their own display programs. One program which reads ASCII data was designed to interface directly with the high resolution color graphics capabilities of the Satellite Data Processing System (SDPS)(Caruso and Dunn, 1989) developed at the Woods Hole Oceanographic Institution. Complete UNIX style manual pages for all programs are included in appendix A.

Most programs have a single input file, a single output file and accept command line arguments as needed. This allows the output of one program to be piped into the input of another program. The simple and modular design of these programs allows users to combine programs to customize more complex programs. Several scripts were written for the UNIX shell (a command line interpreter)³ to utilize this versatile feature. By combining several commands into a shell script, a user can quickly modify the analysis without changing program code and recompiling. For example, a simple shell script to perform a repeat analysis would look similar to this:

```
#
foreach i (c???.$1)
echo $i
#
cat $i | g_clean1 | g_correct | g_clean2 >! tmp
(cat tmp | g_spike | g_spline 1 22 48 3.3 0.97992165 > "$i"c)
end
#
echo Performing repeat analysis.
g_repeat "$i"c > mean."$1"
```

This uses three routines to clean the data, one routine to apply the standard corrections and one routine to spline the data onto an even grid for each cycle of a given

³Several shell programs are available. The examples given use the C shell.

orbit. Then the repeat analysis is done. The script takes as an argument the orbit number.

```
%repeat.sh a002
```

The user could use a program to apply non-standard corrections by substituting the program in the shell script.

```
#
foreach i (c???.$1)
echo $i
#
cat $i | g-clean1 | my_correct | g-clean2 >! tmp
(cat tmp | g-spike | g-spline 1 22 48 3.3 0.97992165 > "$i"c)
end
#
echo Performing repeat analysis.
g-repeat "$i"c > mean."$1"
```

5.1 GEOSAT Programs

A list of available GEOSAT analysis programs is given in table 5 with a brief synopsis. More detailed descriptions of programs are listed below in alphabetical order. All GEOSAT programs begin with *g_* to help provide unique program names.

5.1.1 g-clean1

This program is used to delete raw GEOSAT GDRs which contain obviously bad data. This includes all records that have any of the following variables set to 32767: the sea surface height, *ha*, and the corrections for earth tide, *cet*, ocean tide, *cot*, FNOC wet, *wet_fnoc*, or dry troposphere, *dry_fnoc*, or the ionosphere, *iono*. Records are also removed if the standard deviation, *s_h*, of the 10-per-second sea height values, *h[1] - h[10]*, is greater than 30 cm, or if the backscatter coefficient, *s_naught*, is greater than 35 dB. This program reads in a binary GEOSAT file and removes all bad records. The number of bad records is printed along with the criteria for rejection. For example the command

```
%cat c000.a002 | g-clean1 > c000.a002c
```

produces:

```
g-clean1: Valid points: 345
          Rejected points: 16
          Height: 0
          Solid Tide: 0
          Ocean Tide: 7
          Wet FNOC: 0
          Dry FNOC: 0
          Iono: 0
          Sigma Height: 14
          Sigma Naught: 0
          Flags: 15
```

| List of GEOSAT programs | |
|-------------------------|---|
| Program | Description |
| g_clean1 | Initial cleaning of raw GDRs |
| g_clean2 | Secondary cleaning of GDRs |
| g_compress | Compresses GDR to 18 bytes |
| g_correct | Applies GDR suggested corrections to sea surface height |
| g_crossnum | Converts sequential orbit numbers to equatorial crossing longitudes |
| g_date | Prints start and end date for GDR segment |
| g_date2 | Prints start and end date given cycle and orbit number |
| g_ext | Extracts one or more parameters from GDR and converts to SI units |
| g_image | Converts ASCII GEOSAT data to a bitmap image. |
| g_interp | Linearly interpolates to a specific grid |
| g_print | Decodes GDRs and prints to a terminal |
| g_region | Separates raw GEOSAT GDRs into sequential orbits in a specified region |
| g_repeat | Performs "collinear" or repeat track analysis using a quadratic orbit correction |
| g_repeats | Performs "collinear" or repeat track analysis using a sinusoidal orbit correction |
| g_seporb | Separates raw GEOSAT GDRs into sequential orbits |
| g_spike | Removes data spikes from GDRs |
| g_spline | Splines GDRs to a specific grid |
| g_uncompress | Uncompresses 18 byte data record |
| g_which | Prints orbit numbers in a given lat/lon box |

Table 5:

This shows that a total of 16 records were rejected. Of those 16 records, 15 were rejected because the flag records were bad, 14 were rejected because the standard deviation of the 10-per-second sea height values were greater than 30 cm. Seven were rejected because the ocean tide value was set to 32767. By default, all records over land are also rejected. This most likely accounts for the 15 records rejected because of a bad flag value. This default may be changed to also remove all records over shallow water by specifying the correct flag mask. Any of the available flags supplied in the GEOSAT GDR may be tested. This is done by setting the UNIX environment variable *GMASK*:

```
%setenv GMASK 1 - - - - - 0 - - - - - 0 0
```

where a "-" means ignore this bit, a "0" means skip this record if this bit is not 0 and a "1" means skip this record if this bit is not 1. For more information, see the manual page in appendix A. The results of this program are shown in figure 1.

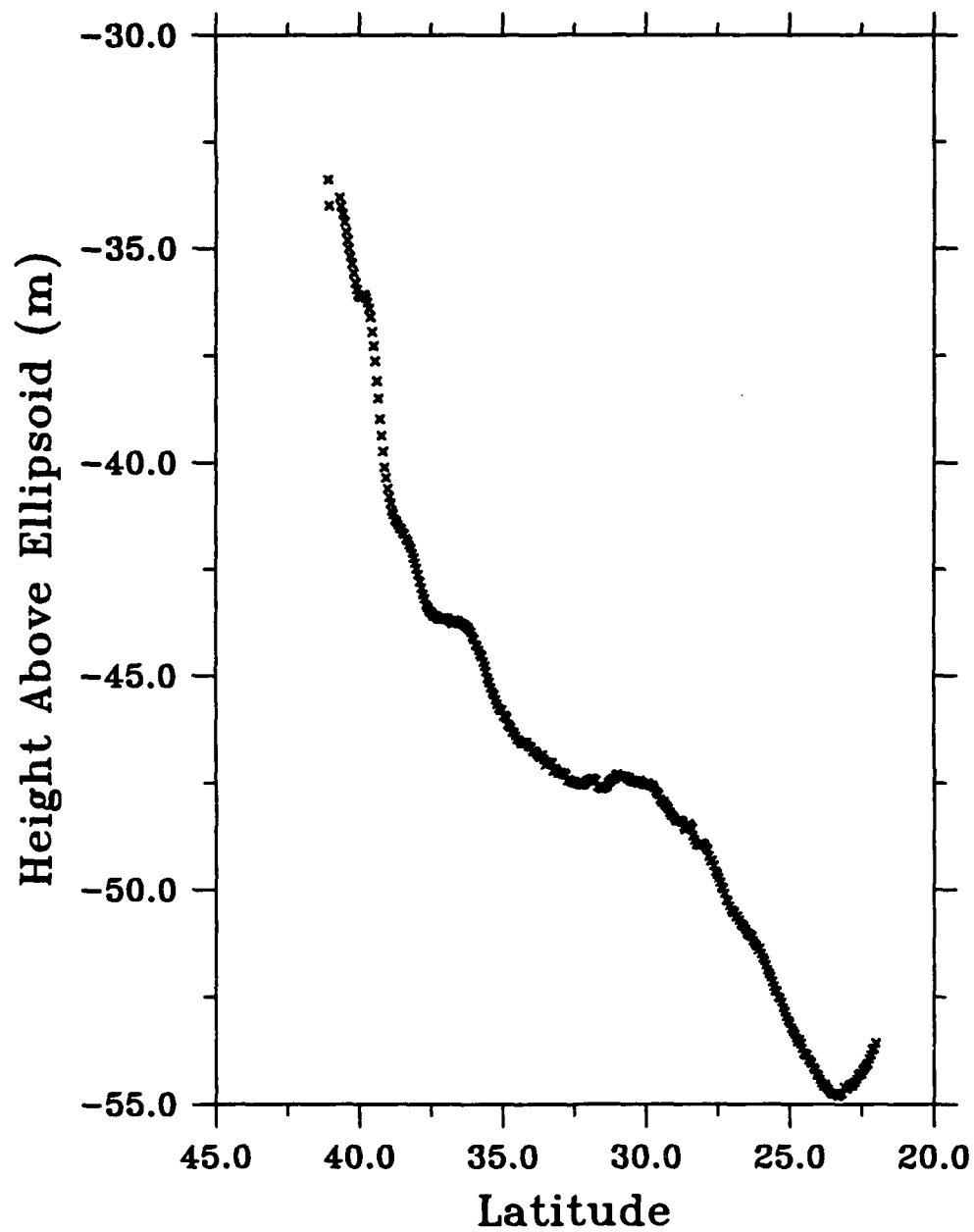


Figure 1: Raw sea surface heights plotted after running program g.clean1 to remove obviously bad data.

| Compressed 18-byte Data Record Contents | | | | |
|---|---------------------|---------------------|-------------|------------------------|
| Item | Parameter | Units | Range | Type |
| 1 | Time | ms | 0 to 1.47E9 | long int (4-bytes) |
| 2 | Height | cm | 0 to 32767 | short int (2-bytes) |
| 3 | Cycle | | 0... | char (1-byte) |
| 4 | Latitude | 10 ⁴ Deg | 0 to 18E5 | unsigned int (3-bytes) |
| 5 | Longitude | 10 ⁴ Deg | 0 to 36E5 | unsigned int (3-bytes) |
| 6 | Sigma Height | cm | 0 to 255 | unsigned char (1-byte) |
| 7 | SWH | 5cm | 0 to 255 | unsigned char (1-byte) |
| 8 | s _{naught} | 0.1dB | 0 to 255 | unsigned char (1-byte) |
| 9 | Flags | | | char (1-byte) |
| 10 | Ocean Tide | cm | -128 to 128 | char (1-byte) |

Table 6:

5.1.2 g_clean2

This program is used to clean up records after *g_clean1* and *g_correct* have been used. It simply removes data records with sea surface heights greater than 10000 cm and less than -14000 cm. This removes any obvious outliers that may interfere with other analysis programs such as *g_spline*. As in *g_clean1*, a total of rejected points is printed. The command

```
%cat c000.a002 | g_clean2 > c000.a002c
```

produces:

```
g_clean2: Rejected points:    0
          Maximum Height:    0
          Minimum Height:    0
```

In this case, file *c000.a002* is the output from *g_clean1* and *g_correct*.

5.1.3 g_compress / g_uncompress

This is a set of programs designed to compress the standard 78-byte GDR to 18 bytes by reducing precision and removing less important fields such as the 10-per-second sea surface heights. The output is an 18-byte-per-record binary file and should be uncompressed before using any of the other analysis programs. These programs were designed for storing as much meaningful data as possible on limited systems. The format of the compressed 18-byte record is given in table 6. The time variable stored is the time since the start of *a000* for each cycle. The other variables are the same as for the full GDR except with reduced precision.

5.1.4 g_correct

This program allows the user to apply one or more of the suggested corrections to the sea surface height value of each record. All suggested corrections are optional and are applied by default. An example of applying all corrections would be:

```
%g_correct < c000.a002 > c000.a002c
```

In this example, the file *c000.a002* is the output from *g_clean1*. The output file *c000.a002c* has the same format as the original GDR, but the height field now contains the following

corrections:

$$h = h - sol_tide - oc_tide - wet_fnoc - dry_fnoc - iono_gps - inv_bar$$

where the corrections are supplied in the GDR (table 1) except for *inv_bar* which is given as follows:

$$inv_bar = -9.948(p - 1013.3)$$

and

$$p = \frac{dry_fnoc}{(-2.277) \{1 + [0.0026 \cos (2LAT)]\}}$$

Individual corrections may be applied by specifying the abbreviation on the command line,

`%g_correct cet cot < c000.a002c > c000.a002c`

This would apply the corrections for the earth tide and the ocean tide supplied with the GEOSAT GDR. The list of available abbreviations is given in table 7 and in the manual page in appendix A. These abbreviations also correspond to the abbreviations for *g_ext*. The corrections for a section of *c000.a002* are given in figure 2.

| Description of variables for program g_correct | |
|--|--|
| Abbreviation | Description |
| cet | correction for earth tide in m |
| cot | correction for ocean tide in m |
| cwf | correction for wet troposphere fnoc |
| cws | correction for wet troposphere smmr |
| cdf | correction for dry troposphere |
| ci | correction for ionosphere |
| cib | correction for inverse barometric effect |

Table 7:

5.1.5 g_crossnum

This program finds the longitude where a given orbit crosses the equator. This program was designed to convert sequential orbit numbers to equatorial crossing numbers. The program may be used in two ways. First, the specific orbit can be specified:

`%g_crossnum a002`
`306.43`

Second, the program may be given a GEOSAT GDR:

`%g_crossnum < c000.a002`
`306.43`

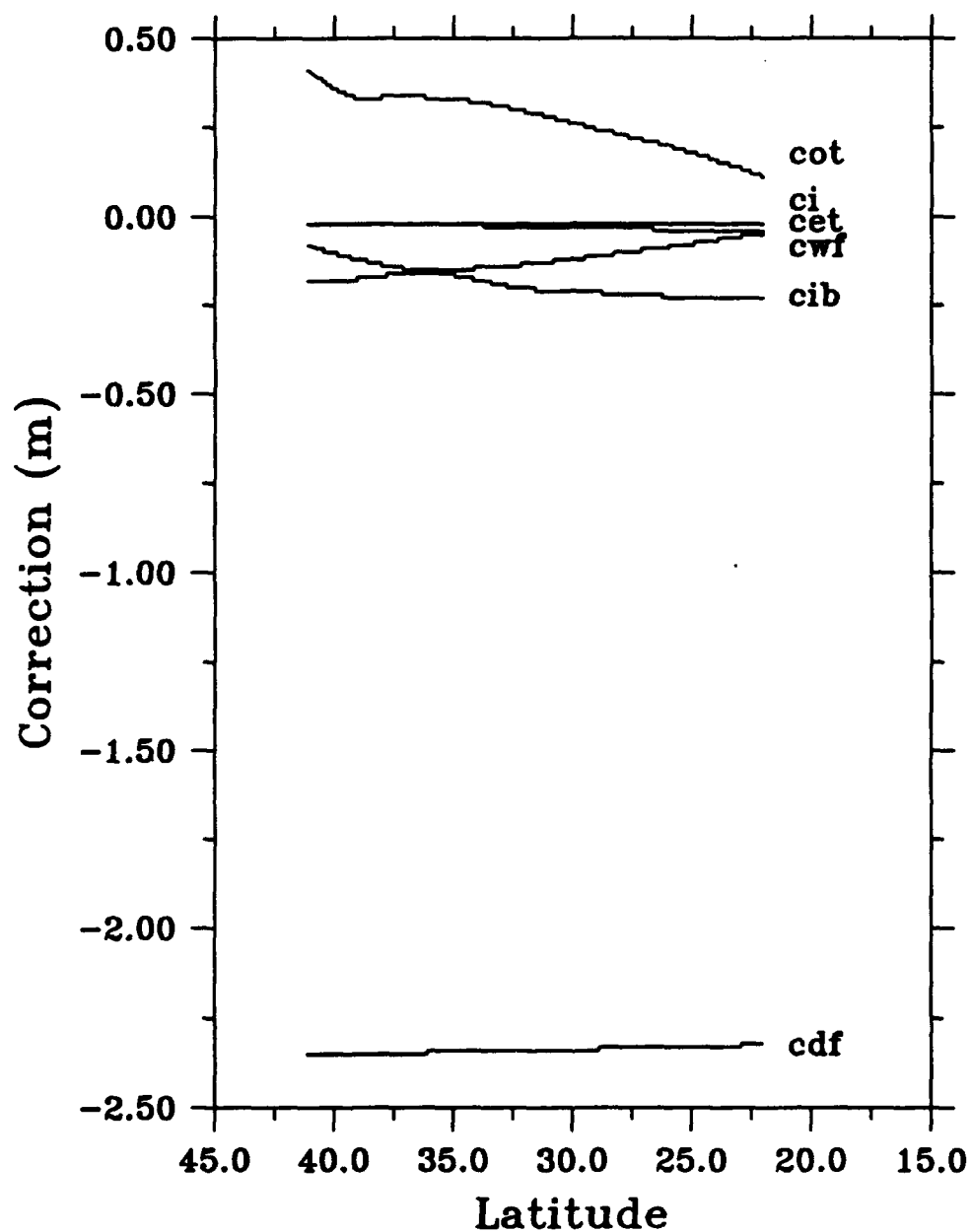


Figure 2: Corrections from a section of orbit c000.a002. *Cot* is for the ocean tide; *ci* is for the ionosphere; *cet* is for the earth tide; *cwf* is for the FNOc wet troposphere; *cib* is for the inverse barometric effect and *cdf* is for the FNOc dry troposphere.

5.1.6 g_date

This program prints the start and end date and time of a GEOSAT GDR segment. The program prints the *utc* value from the GDR, the date, the day of year, the Julian day and the day of the cycle.

```
%cat c053.a002 | g_date
UTC: 136497764.05
Date: 4/28/89 20:02:44
Day of year: 118
Julian: 1753685
Day of cycle: 0

UTC: 136498110.94
Date: 4/28/89 20:08:30
Day of year: 118
Julian: 1753685
Day of cycle: 0
```

5.1.7 g_date2

This program is similar to *g_date* except that it takes the orbit and cycle numbers as arguments. The program prints the approximate beginning and ending times of the specified orbit.

```
%g_date2 053 002
UTC: 136492860.00
Date: 4/28/89 18:41:00
Day of year: 118
Julian: 1753685
Day of cycle: 0

UTC: 136498897.00
Date: 4/28/89 20:21:37
Day of year: 118
Julian: 1753685
Day of cycle: 0
```

5.1.8 g_ext

This program was written to convert and extract one or more parameters in a GEOSAT GDR to ASCII format. It converts all parameters to SI units. To create an ASCII file of the latitude, longitude and uncorrected sea surface heights, the following command would be given:

```
%g_ext l L ha < c000.a002 > c000.a002asc
```

where *c000.a002* is a file containing GDRs in binary format and *c000.a002asc* is the ASCII output from *g_ext*. This program allows the user to use almost any plotting package to display the data. For example, the command

```
%g_ext l w < c000.a002 | graph -g 1 -x 45 20 -5
```

uses the standard UNIX plotting utility *graph* to plot the significant wave height for orbit number 002 in cycle 000 over the Gulf Stream for figure 3. Compare this with the clean data plotted after using *g_clean1* in figure 1 to see how obviously bad points can be removed. The complete list of abbreviations is given in table 8 and in the manual page in appendix A. Figures 4 and 5 are examples of other fields that may be extracted and plotted using more sophisticated plotting packages.

| Description of variables for program g_ext | |
|--|---|
| Abbreviation | Description |
| t | time in seconds since equator crossing of orbit c000.a000 |
| l | latitude in degrees |
| L | east longitude in degrees |
| ho | orbit height above ellipsoid in m |
| ha | sea surface height above ellipsoid in m |
| sha | sigma ha |
| hg | geoid height above ellipsoid in m |
| w | significant wave height |
| sw | sigma w |
| so | backscatter coefficient in 0.01 dB |
| ag | agc in 0.01 dB |
| sag | sigma ag |
| fl | masked flags |
| HA | land surface height offset above ellipsoid |
| cet | correction for earth tide in m |
| cot | correction for ocean tide in m |
| cwf | correction for wet troposphere fnoc |
| cws | correction for wet troposphere smmr |
| cdf | correction for dry troposphere |
| ci | correction for ionosphere |
| b | attitude bias |
| bc | compression bias |
| att | attitude |
| cib | correction for inverse barometric effect |
| h | corrected sea surface height above ellipsoid |
| dh | corrected sea surface height above geoid |

Table 8:

5.1.9 g_image

This program converts ASCII GEOSAT data in the form *latitude*, *longitude* and *z* to a bitmap image. An example of Gulf Stream variability calculated from the repeat track analysis using ascending orbits is shown in figure 6. The coastline and grid overlays on this figure were generated using SDPS.

This program takes six parameters, the minimum latitude and longitude, the maximum latitude and longitude and the number of rows and columns in the output image. The following was used to generate the image in figure 6:

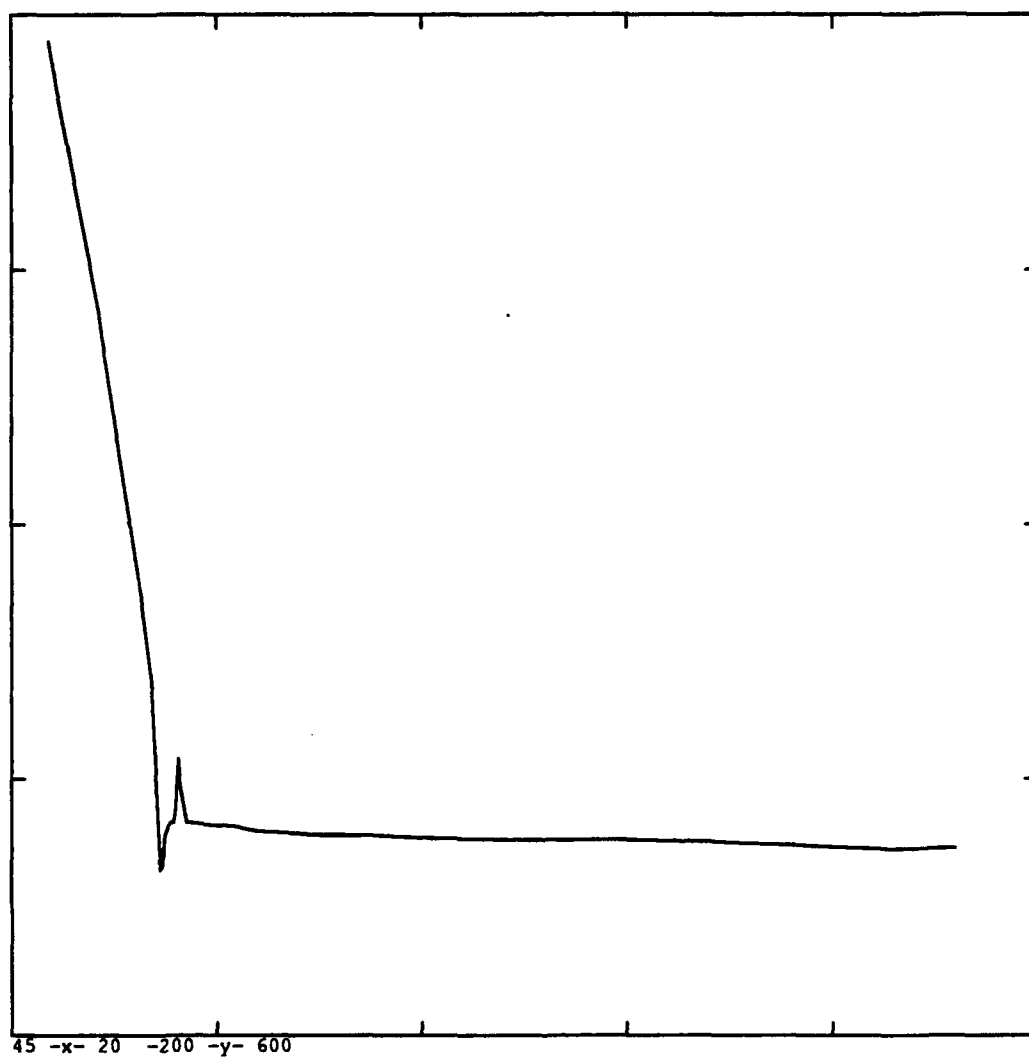


Figure 3: An example of using *g-ext* to extract raw sea surface heights. The UNIX utility *graph* was used to plot this figure.

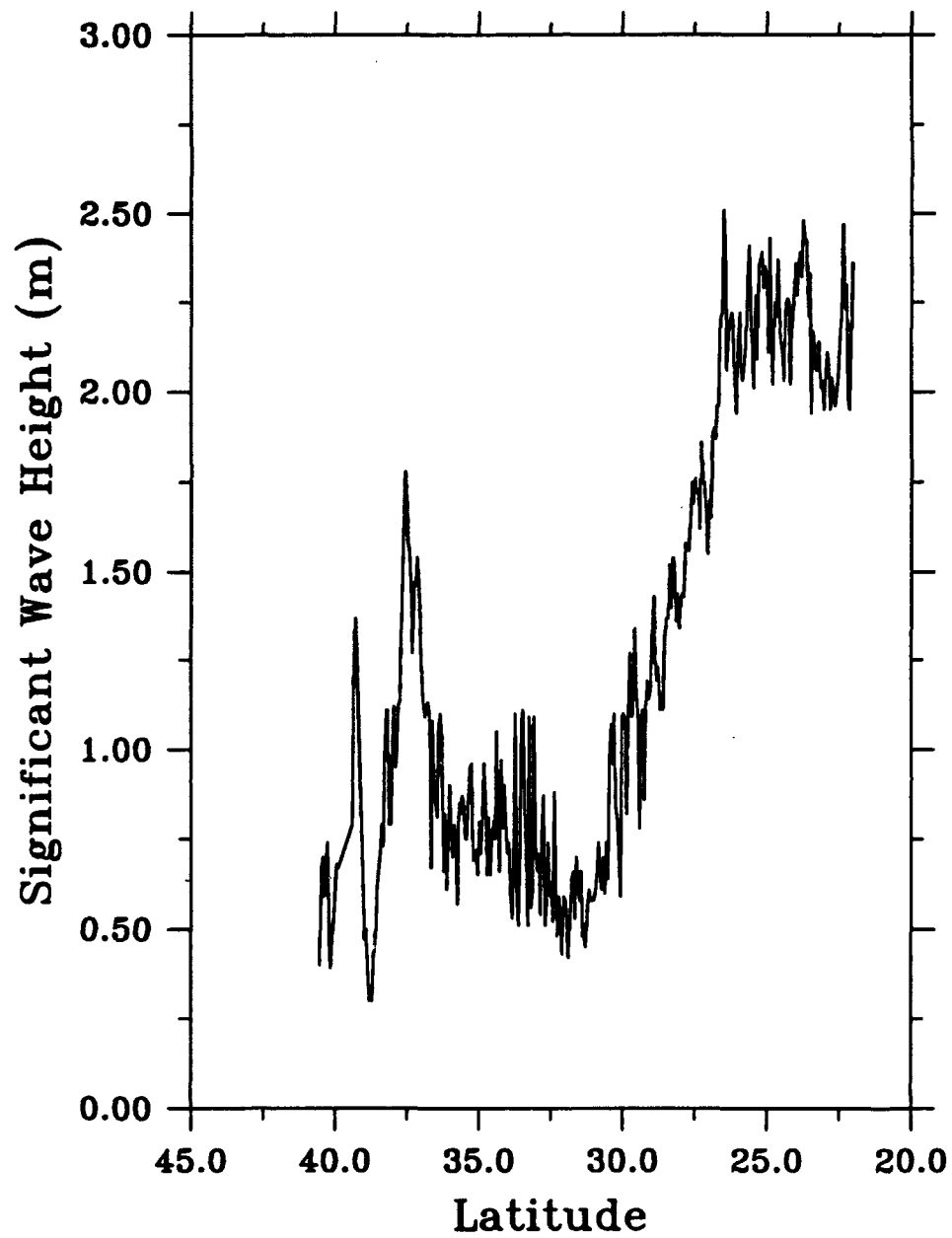


Figure 4: An example of using *g_ext* to extract the significant wave heights for orbit c000.a002 over the Gulf Stream.

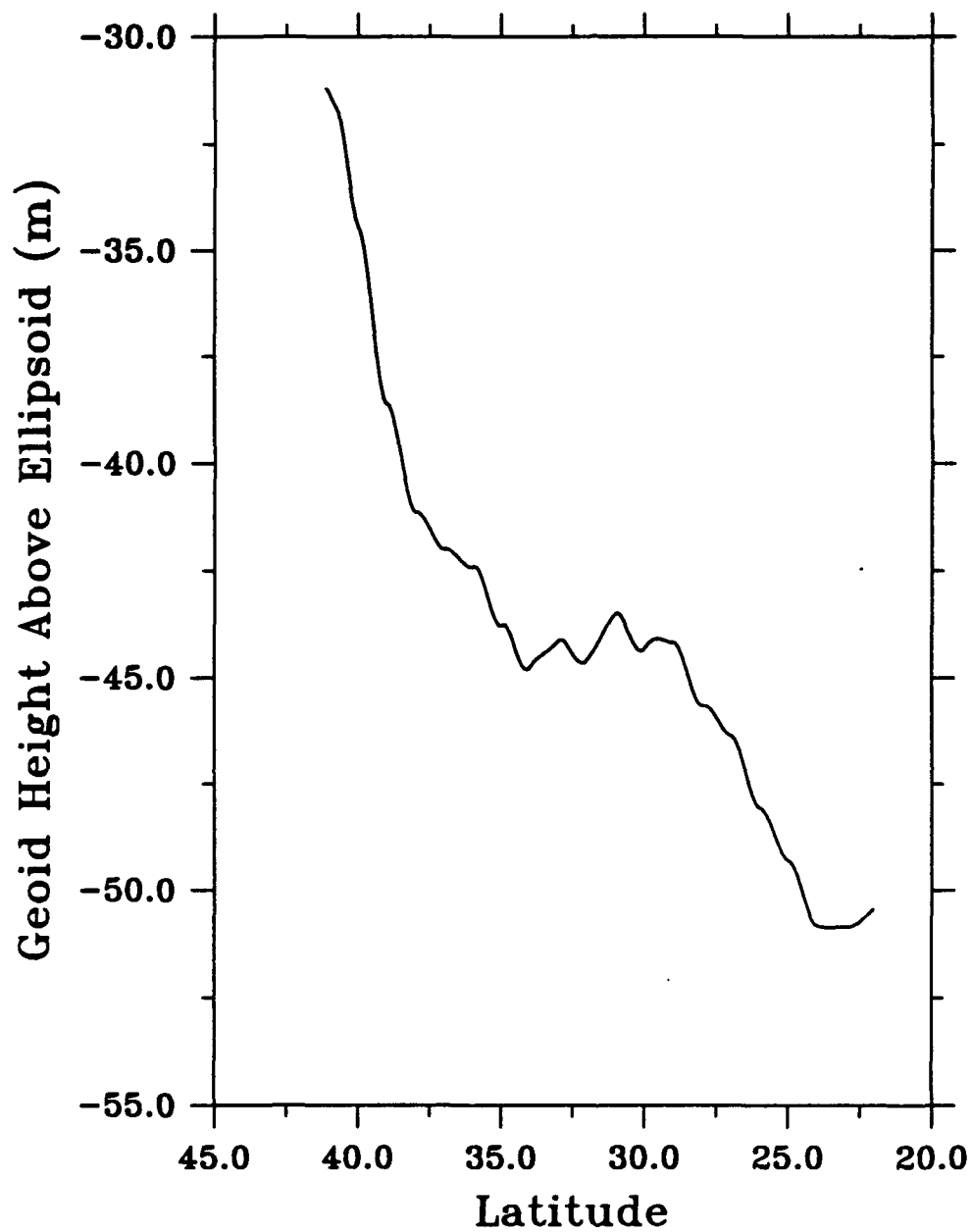


Figure 5: An example of using *g_ext* to extract included geoid heights for orbit c000.a002 over the Gulf Stream.


```
%cat a*cs_m | cut -f2,5 | g_image 22 48 284 316 416 512 > vara.sdpsf
```

The input is all the output files from *g-repeat* for each orbit in the region. The command *cut* is a standard UNIX command and illustrates how these programs are designed to be used with existing commands. The output image has 416 rows, 512 columns and is on an equirectangular grid 22N, 284E to 48N, 316E. This image is in SDPS floating point format and may be converted to byte format for display using the SDPS routine *sdps_ftb*:

```
%cat vara.sdpsf | sdps_ftb > vara.sdps
```

5.1.10 g_interp

This program is used to regrid the GEOSAT data to a common grid by linearly interpolating between supplied data points. All variables in the GDR are interpolated except the 10-per-second sea surface heights and the data flags since these fields are no longer meaningful to the regridded data. The output is regridded so that at least one value is positioned on the equator. This ensures that segments from areas that overlap, i.e. 10° N to 40° N and 25° N to 50° N, can be directly compared. The output file contains complete segments in GDR format.

Input segments should be cleaned and corrected and five arguments are required by the program:

```
%cat c000.a002 | g_interp dir min max gap delta_t > c000.a002c
```

where *dir* is 1 for an interpolation bounded by a minimum and maximum latitude and 2 for an interpolation bounded by a minimum and maximum longitude (see *g-region* section 5.1.12). A *gap* is the maximum time between good segments. The program does not spline across gaps, but labels the points as bad (32767). Gaps and incomplete cycles are filled to the boundaries defined by *min* and *max* with the correct latitude. The time between interpolated points is *delta_t*. One point is placed on the equator crossing and subsequent points are splined *delta_t* seconds apart. There are no default parameters. An example for the Gulf Stream region is:

```
%cat c000.a002 | g_interp 1 22 48 3.3 0.97992165 > c000.a002c
```

Here, the data is interpolated between 22° N and 48° N. If the segment has more than 3.3 seconds of missing data, it is considered to be a gap. The output points are interpolated to be 0.97992165 seconds apart, which is the same spacing as the raw GDRs.

5.1.11 g_print

This program decodes each GEOSAT GDR and prints the variables to a terminal. An example of the output is shown below:

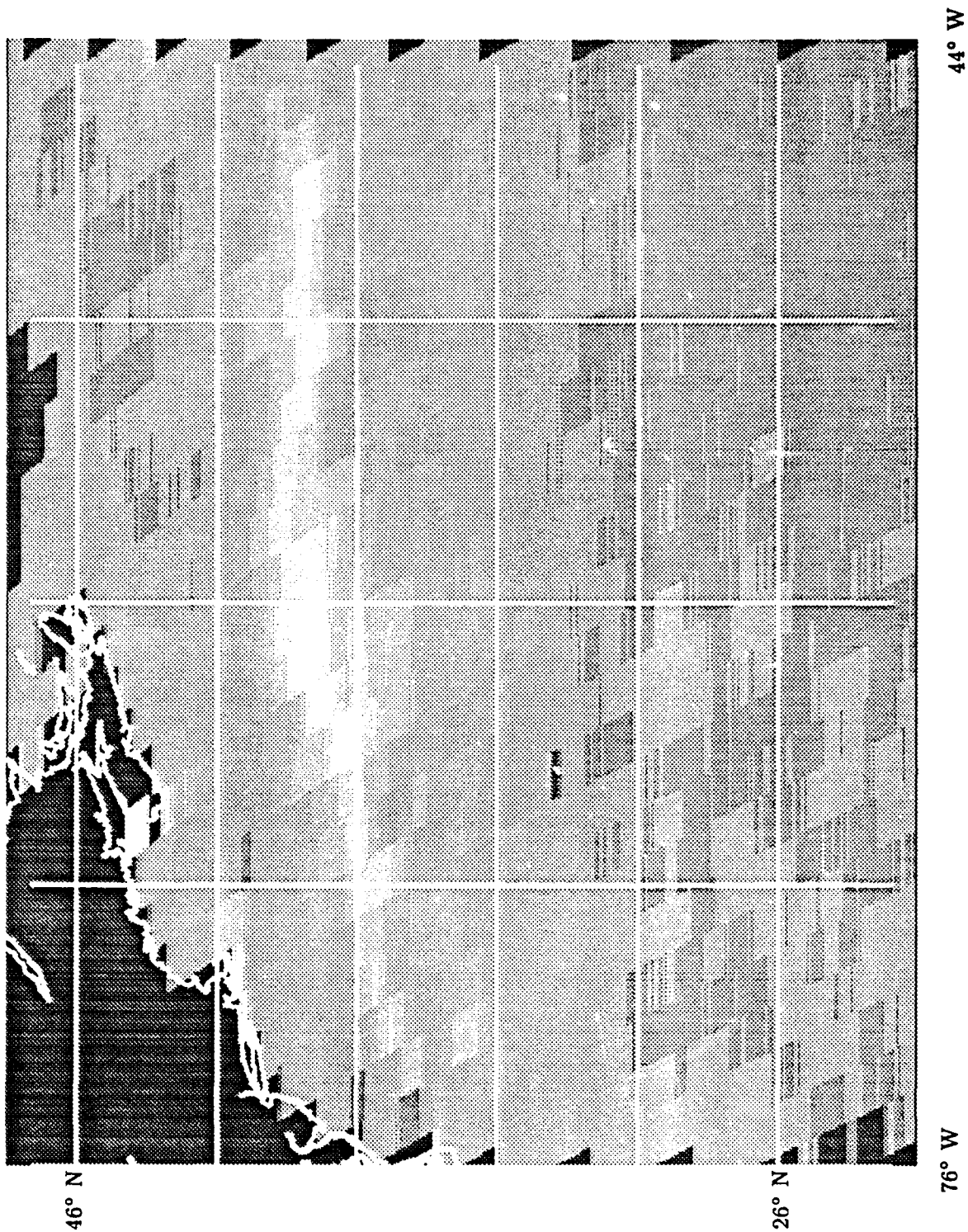


Figure 6: An example of an image generated using g_image. The grey shades represent the sea surface height variability and the coastlines were overlaid using SDPS.

Record Number: 1

| | | | | | |
|----------|---|-----------|--------|---|-----------|
| utc | : | 58939389 | utcm | : | 203366 |
| lat | : | 22017008 | lon | : | 300236639 |
| orb | : | 789454644 | | | |
| m_h | : | -5353 | s_h | : | 4 |
| geoid | : | -4872 | | | |
| h[1] | : | -5349 | h[2] | : | -5348 |
| h[3] | : | -5349 | h[4] | : | -5348 |
| h[5] | : | -5349 | h[6] | : | -5349 |
| h[7] | : | -5358 | h[8] | : | -5365 |
| h[9] | : | -5359 | h[10] | : | -5359 |
| sw_h | : | 253 | s_sw_h | : | 11 |
| s_naught | : | 1088 | | | |
| agc | : | 2664 | s_agc | : | 2 |

flags (0-15 right to left): 0000010000000011

| | | | | | |
|----------|---|------|----------|---|-------|
| h_off | : | 0 | | | |
| sol_tide | : | 188 | oc_tide | : | -177 |
| wet_fnoc | : | -252 | wet_smmr | : | -242 |
| | | | dry_fnoc | : | -2325 |
| iono_gps | : | -16 | | | |
| dh_sw_h | : | 38 | | | |
| dh_fm | : | 30 | | | |
| att | : | 74 | | | |

where the units and names correspond to those given in table 1.

5.1.12 g_region

This program reads raw GEOSAT GDRs and separates them into individual ascending and descending orbits and extracts data from a user-specified region. The user may specify two types of regions. The first type of region is bounded by latitude lines, and the second is bounded by longitude lines. Figure 7 shows the ascending orbits extracted from a data set over the Gulf Stream bounded by latitude lines.

The smaller box in fig. 7 shows the latitude/longitude boundaries given to the program (22° N - 48° N, 284° E - 316° E). GDR segments were truncated at the minimum and maximum latitudes, but not at the minimum and maximum longitudes. This was done in order to keep reasonable ground track lengths in corners of the box since short segments would be useless for repeat analysis. Note that all the orbits to the right of the box actually extend until they intersect with the 22° N latitude line. This particular region was extracted using the command:

```
%g_region 1 22.0 48.0 284.0 316.0 < raw_geo
```

To extract files directly from the NODC HP format tape:

```
%dd if=/dev/rmt8 ibs=16380 files=34 | g_region 1 22.0 48.0 284.0 316.0
```

This command would extract the region shown in figure 7 and separate the data into ascending and descending orbits using the naming convention previously described in section 4. Since orbits may be split between tapes or tape files, the data is appended

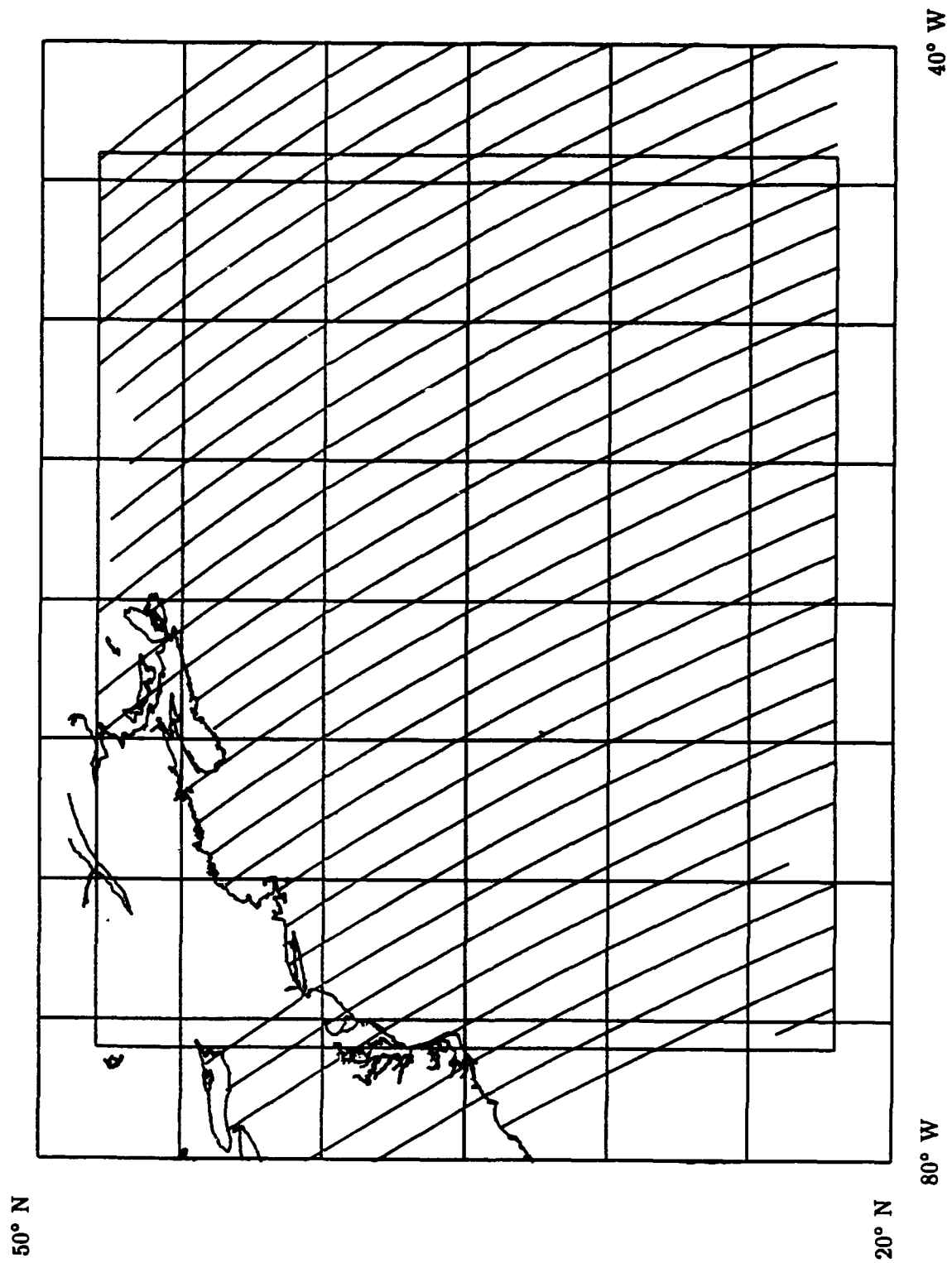


Figure 7: Ascending ground tracks of a region of the Northwest Atlantic.

to any existing files. This provides complete segments even if an orbit is split between data tapes or extracted data files. Since extracted regions do not have unique names, files should be moved or deleted if additional regions are to be extracted from the same tape. This prevents discontinuous regions from being appended together under the same file name.

Optional orbit numbers may be specified on the command line. If orbits are given, only the orbits which fall within the region are removed. To extract only orbits 002 and 088 the following command would be used:

```
%dd if=/dev/rmt8 ibs=16380 files=34 | g_region 1 22.0 48.0 284.0 316.0 2 88
```

5.1.13 g-repeat

This program performs a repeat track analysis of GEOSAT GDRs and assumes that all the GDRs have been cleaned (*g_clean1*, *g_clean2*), corrected (*g_correct*) and splined (*g_spline*) or interpolated (*g_interp*) to a uniform grid. It also assumes that each cycle contains the same start and end points. The program reads in all available GDRs and calculates the mean sea surface height for each grid point. If a sea surface height is set to 32767, the point is assumed to be bad and is not used to find the mean. This mean height profile, averaged over all cycles, is then subtracted from each individual track to produce a residual sea surface height profile:

$$h(x_i, t) - \langle h(x) \rangle = \hat{y}(x_i, t) \quad (1)$$

where x_i is the location along the subtrack, t is the cycle number, $h(x_i, t)$ is the cleaned and corrected sea surface height profile, $\langle h(x) \rangle$ is the initial estimate for the mean height profile, and $\hat{y}(x_i, t)$ is the residual sea surface height. A quadratic function, $a(t)x_i^2 + b(t)x_i + c(t)$, is calculated for each residual height for each cycle t using a least squares fit which minimizes:

$$\epsilon^2 = \sum_{x_i}^n \left\{ \hat{y}(x_i, t) - [a_1(t)x_i^2 + b_1(t)x_i + c_1(t)] \right\}^2 \quad (2)$$

This quadratic estimate of the orbit error is removed from the residual height for each cycle to obtain a new residual height, \hat{z} , where

$$\hat{z}(x_i, t) = \hat{y}(x_i, t) - [a_1(t)x_i^2 + b_1(t)x_i + c_1(t)] \quad (3)$$

The variance, σ^2 , of all the height residuals \hat{z} for each subtrack is calculated by:

$$\sigma^2(x_i) = \frac{1}{N(x_i)} \sum_{t=0}^N \{ \hat{z}(x_i, t) \}^2 \quad (4)$$

where $N(x_i)$ is the number of good data at the point x_i . A second quadratic, weighted by the inverse of the variance, is fit to the residual \hat{z} to minimize:

$$\epsilon^2 = \sum_{x_i}^n \left\{ \hat{y}(x_i, t) - [a_2(t)x_i^2 + b_2(t)x_i + c_2(t)] \right\}^2 \frac{1}{\sigma^2(x_i)} \quad (5)$$

The resulting quadratic orbit error estimate is then removed from each profile to obtain a corrected height profile:

$$\tilde{h}(x_i, t) = h(x_i, t) - [a_2(t)x_i^2 + b_2(t)x_i + c_2(t)] \quad (6)$$

and the geoid profile, $g(x_i)$, is calculated by averaging the corrected height profiles, $\langle \bar{h}(x_i, t) \rangle$. The sea surface height residuals are calculated for each cycle:

$$h'(x_i, t) = \bar{h}(x_i, t) - g(x_i) \quad (7)$$

and written to separate files based on the input file names. The geoid and sea surface height variability are also printed. Typically, the program is called using "*" or "?" wildcard file specifications:

`%g_repeat c*/c*.a002c > a002cs_m`

or

`%g_repeat c???/c???.a002c > a002cs_m`

The file `a002cs_m` contains the following information in tab delimited columns:

`x_i lat(x_i) lon(x_i) g(x_i) sigma^2(x_i) sum x^2 N(x_i)`

where x_i is a sequential counter of the points in the orbit section, $lat(x_i)$ and $lon(x_i)$ are the latitude and longitude at x_i , $g(x_i)$ is the estimated geoid, $\sigma^2(x_i)$ is the sea surface height variability, $\sum x^2$ is the sum of the squares of the sea surface heights and $N(x_i)$ is the number of cycles of good data found.

The sea surface height residuals, $h'(x_i, t)$, are written to a file in the same directory as the original raw data. The new file name is the same as the original with an `_r` appended to it, e.g., `c000.a002` would become `c000.a002_r`. Each file contains the following information:

`x_i lat(x_i) lon(x_i) h'(x_i, t) f_1(x_i, t) f_2(x_i, t)`

where x_i , $lat(x_i)$, $lon(x_i)$ are the same as in the file described above; $h'(x_i, t)$ is the corrected sea surface heights with the estimated geoid removed; $f_1(x_i, t)$ is the original quadratic fit $[a_1(t)x_i^2 + b_1(t)x_i + c_1(t)]$ and $f_2(x_i, t)$ is the weighted quadratic fit $[a_2(t)x_i^2 + b_2(t)x_i + c_2(t)]$.

5.1.14 g_repeats

This program is identical to `g_repeat`, except that a sinusoidal orbit correction is used. Here a sinusoidal estimate of the orbit error is removed from the residual height to obtain a new residual, \hat{z} , where equation 3 becomes

$$\hat{z}(x_i, t) = \hat{y}(x_i, t) - [a_1 \sin(\frac{2\pi t}{T} + \phi_1) + b_1] \quad (8)$$

where t is the time of the GDR and T is the orbital period.

Similarly, equations 5 and 6 become

$$\epsilon^2 = \sum_{x_i} \left\{ \hat{y}(x_i, t) - [a_2 \sin(\frac{2\pi t}{T} + \phi_2) + b_2] \right\}^2 \frac{1}{\sigma^2(x_i)} \quad (9)$$

$$\bar{h}(x_i, t) = h(x_i, t) - [a_2 \sin(\frac{2\pi t}{T} + \phi_2) + b_2] \quad (10)$$

The program is used the same as `g_repeat` using "*" or "?" wildcard specifications:

```
%g_repeat c*/c*.a002c > a002cs.m
```

or

```
%g_repeat c??/c???.a002c > a002cs.m
```

Similarly, the file *a002cs.m* contains the following information in tab delimited columns:

```
xi lat(xi) lon(xi) g(xi) σ2(xi) Σ x2 N(xi)
```

The sea surface height residual files are similar to those created by *g_repeat*:

```
xi lat(xi) lon(xi) h'(xi,t) f1(xi,t) f2(xi,t)
```

except that $f_1(x_i, t)$ is the original sinusoidal fit $a_1 \sin(\frac{2\pi t}{T} + \phi_1) + b_1$ and $f_2(x_i, t)$ is the weighted sinusoidal fit $a_2 \sin(\frac{2\pi t}{T} + \phi_2) + b_2$.

Figure 8 shows a comparison of the orbit corrections for both the quadratic and sinusoidal fit. The solid line represents the initial correction and the dashed line represents the weighted correction. The initial corrections both peak at 33° N which is near where the ground track crosses Bermuda. The weighted corrections are less influenced by Bermuda, but clearly the quadratic is still influenced.

5.1.15 g_seporb

This program was designed to separate raw GEOSAT data into separate orbits and number the files as described above. This is similar to *g_region* except that complete orbits are extracted from the original data instead of partial orbits within specific regions. The file naming conventions are consistent with *g_region* as described in section 4. To separate all orbits from the NODC HP format tape:

```
%dd if=/dev/rmt8 ibs=16380 files=34 | g_seporb
```

5.1.16 g_spike

This program was designed to remove data spikes from the data record. An example of data spikes is given in figure 9. This is data that passes through *g_clean1* and *g_clean2* without being removed.

This type of point may cause overshoot problems when the GDRs are splined using *g_spline* or may bias the repeat analysis. In any case, the data point is questionable and should be removed.

This program filters spikes by fitting a quadratic function or polynomial to a set of points in a least squares sense. Each orbit is split into contiguous segments where a discontinuity is defined as a gap between data points of 3.3 seconds or more. A polynomial is fit through each segment that contains at least 13 points. If a segment contains less than 13 points, it is removed from the record. If the point in question is more than 0.20 meters different from the quadratic fit, the two worst points are removed and a second 11 point quadratic is fit. If the point is still more than 0.20 meters from the polynomial, a straight line is fit through the data and the point is finally rejected if it is more than 0.20 meters from the line. The plot in figure 9 shows the result of *g_spike* for orbit *c022.a160*:

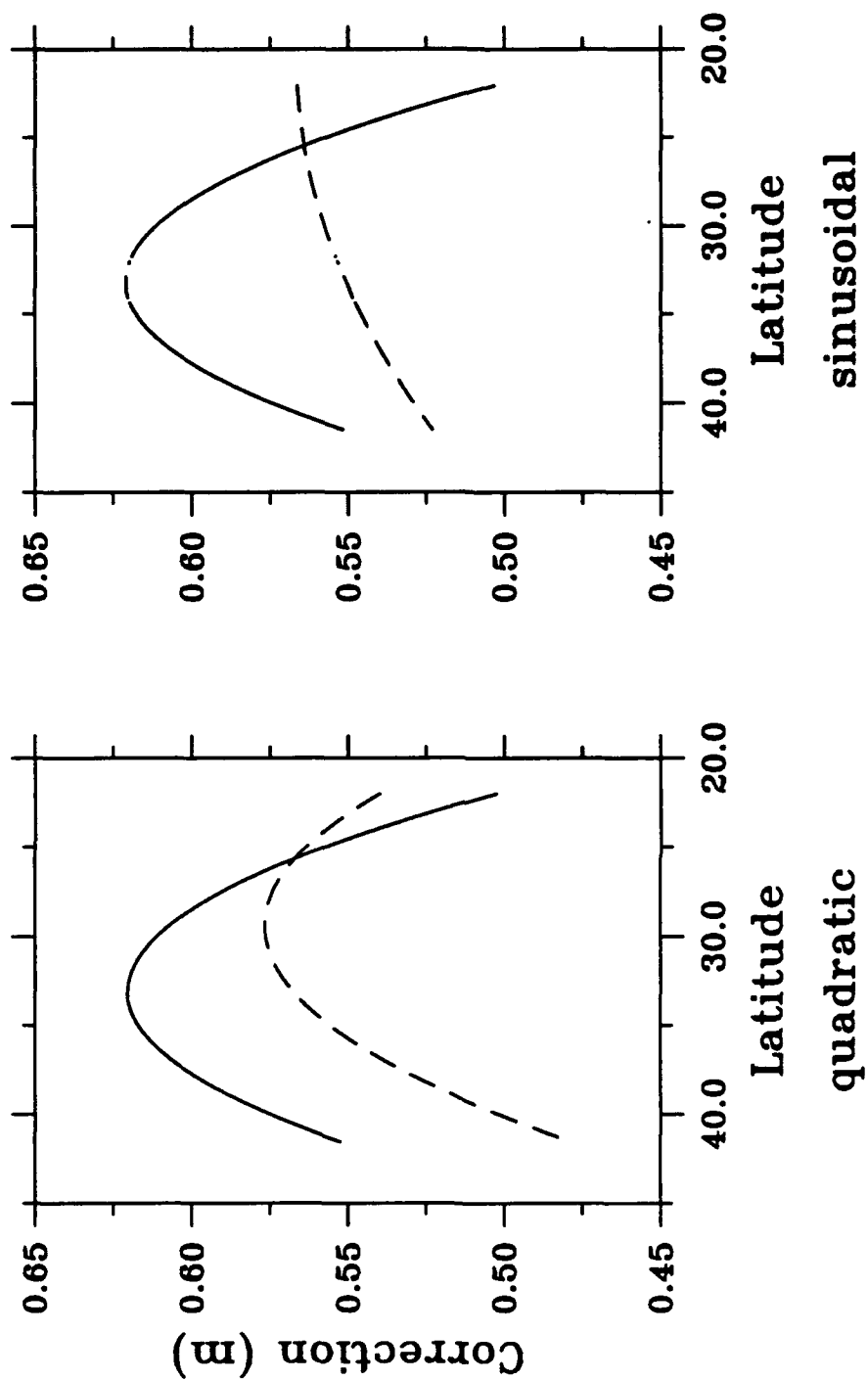


Figure 8: Orbit corrections of cycle *c000*, orbit *a088* for a quadratic fit (left) and a sinusoidal fit (right). The solid line is the initial correction and the dashed line is the weighted correction.

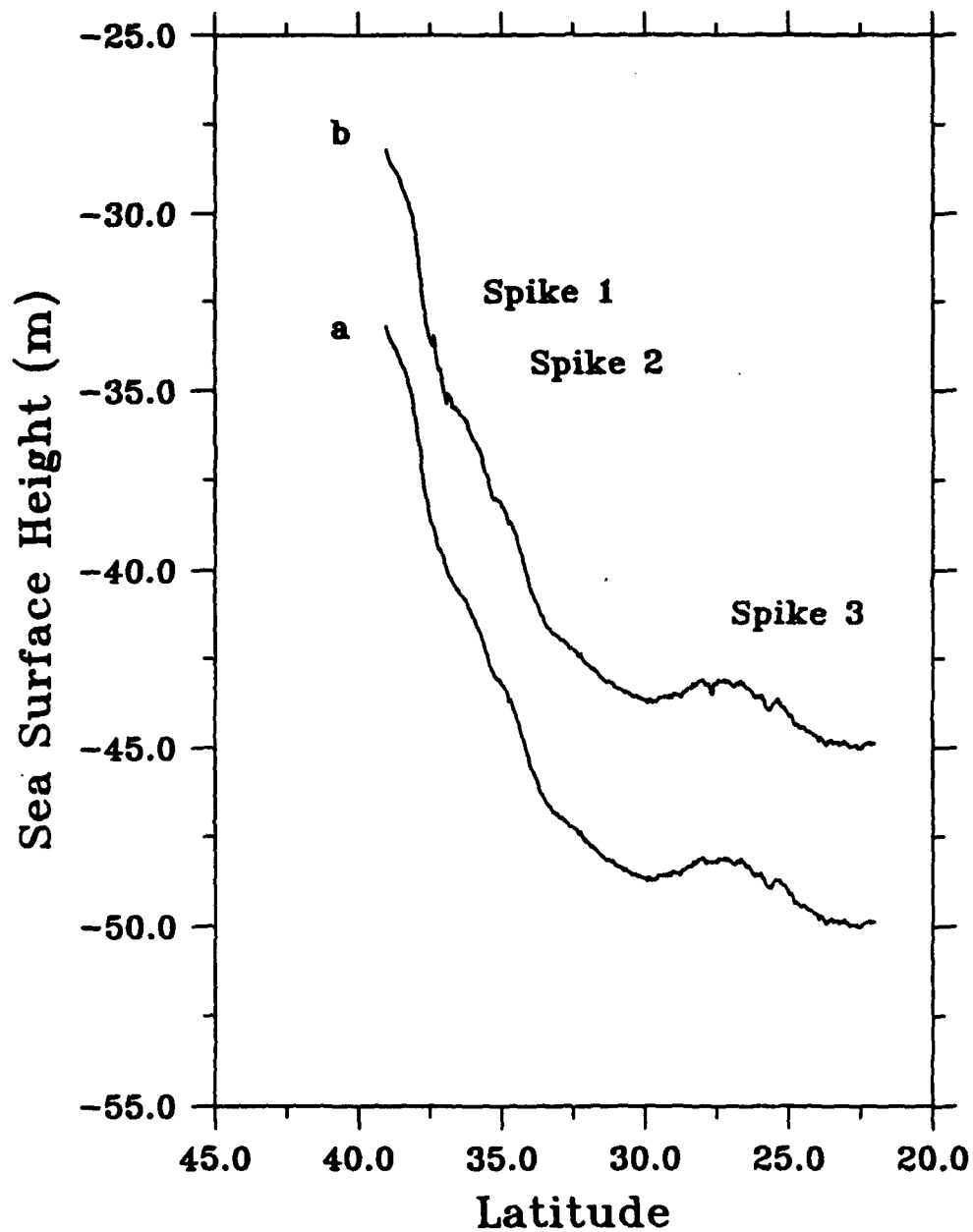


Figure 9: An example of the effect *g_spike* parameters have on data spikes for orbit c022.a160 over the Gulf Stream offset for clarity. Line a results from the default parameters where 3.3 seconds data gap, 13 fit points and 0.20 meter tolerance; b results from 3.3 second data gaps, 9 fit points and 0.50 meter tolerance.

```
%cat c022.a160c | g_spike > c022.a160cs
```

Since the default parameters are moderately restrictive, some data spikes may be retained or some valid data points may be rejected. It is important to check the results for spikes or missing data. The size of the data gap, the number of points and the height difference between the spline and the point being tested may be specified to fine tune the program:

```
%cat c022.a160 | g_spike 3.3 9 0.5 > c022.a160c
```

This command would split the data into segments separated by 3.3 seconds or more. The initial spline would contain 9 points and the second spline would contain 7 points. Each point would be rejected if it differed by more than 0.5 meters from each of the splines described above. For some orbits such as *a160*, these parameters can retain spikes (figure 9.) Although these spikes are negligible in the mean (figure 10), they can be important in the height residual (figure 11).

5.1.17 *g_spline*

This program will spline all the data in a given GDR except the 10-per-second heights and the data flags to a uniform calculated latitude grid, which has at least one value on the equator. This program is designed to be interchangeable with *g_interp* so the output also contains complete segments and the input is assumed to be cleaned and corrected GDRs. Also, the same 5 arguments are given on the command line and there are no defaults:

```
cat c000.a002 | g_spline dir min max gap delta.t > c000.a002c
```

where *dir* is 1 for a spline bounded by a minimum and maximum latitude and 2 for a spline bounded by a minimum and maximum longitude. Missing records are filled with the correct latitude and data values are labeled as bad points (32767). *Min* and *max* are the minimum latitude or longitude to spline between. *Gap* is the maximum time in seconds between continuous segments. The program does not spline across gaps, but labels the points as bad. *Delta.t* is the interpolation time step. One point is placed on the equator crossing and subsequent points are splined *delta.t* seconds apart. For the ascending orbits shown in figure 7, commands similar to the following were used:

```
cat c000.a002 | g_spline 1 22.0 48.0 3.3 0.97992165 > c000.a002c
```

The value of 0.97992165 was chosen to correspond to the actual separation of one-per-second GDRs.

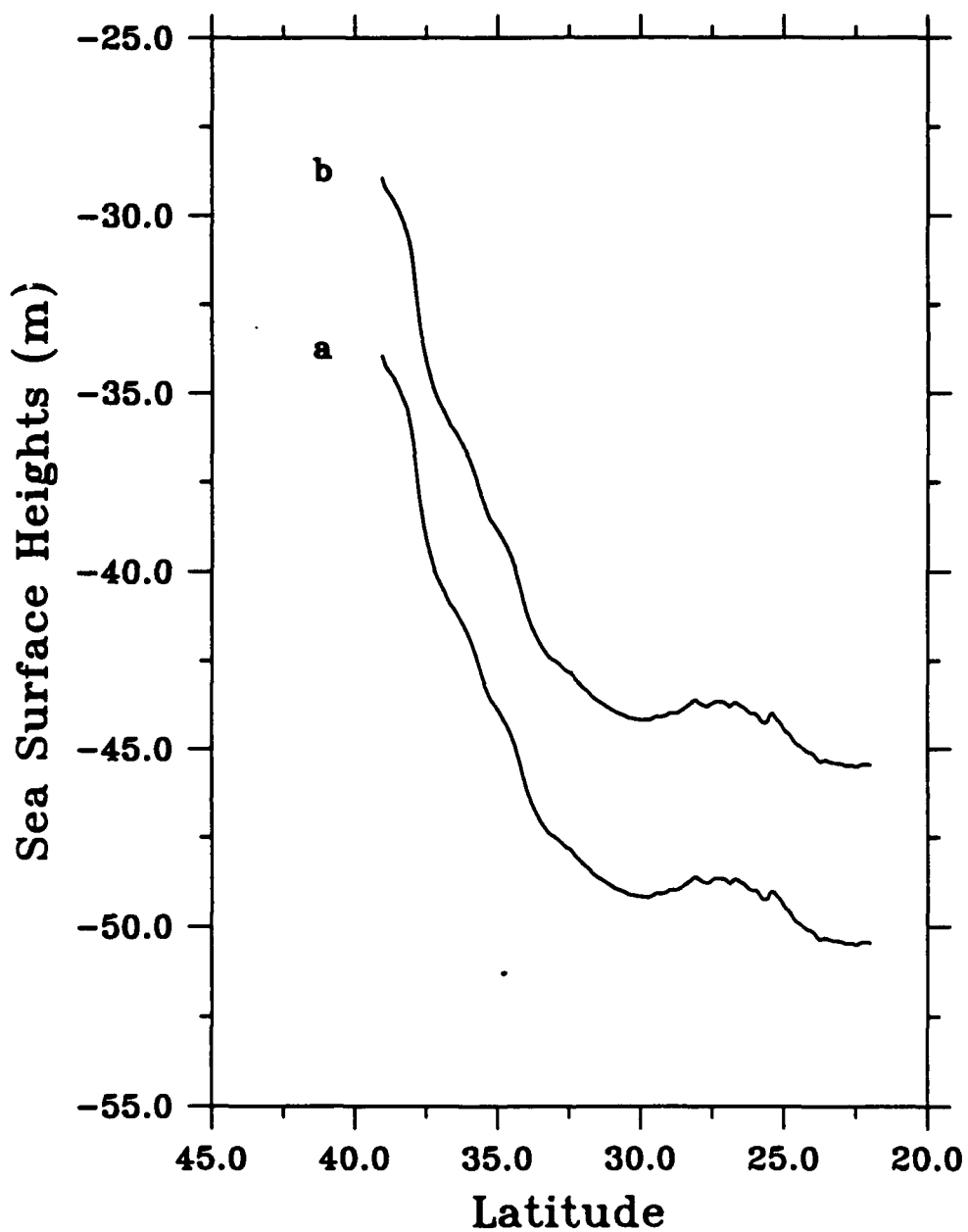


Figure 10: An example of the effect data spikes have on the mean for orbit c022.a160 over the Gulf Stream. Line a results from the default parameters and b results from 3.3 second data gaps, 9 fit points and 0.50 meter tolerance.

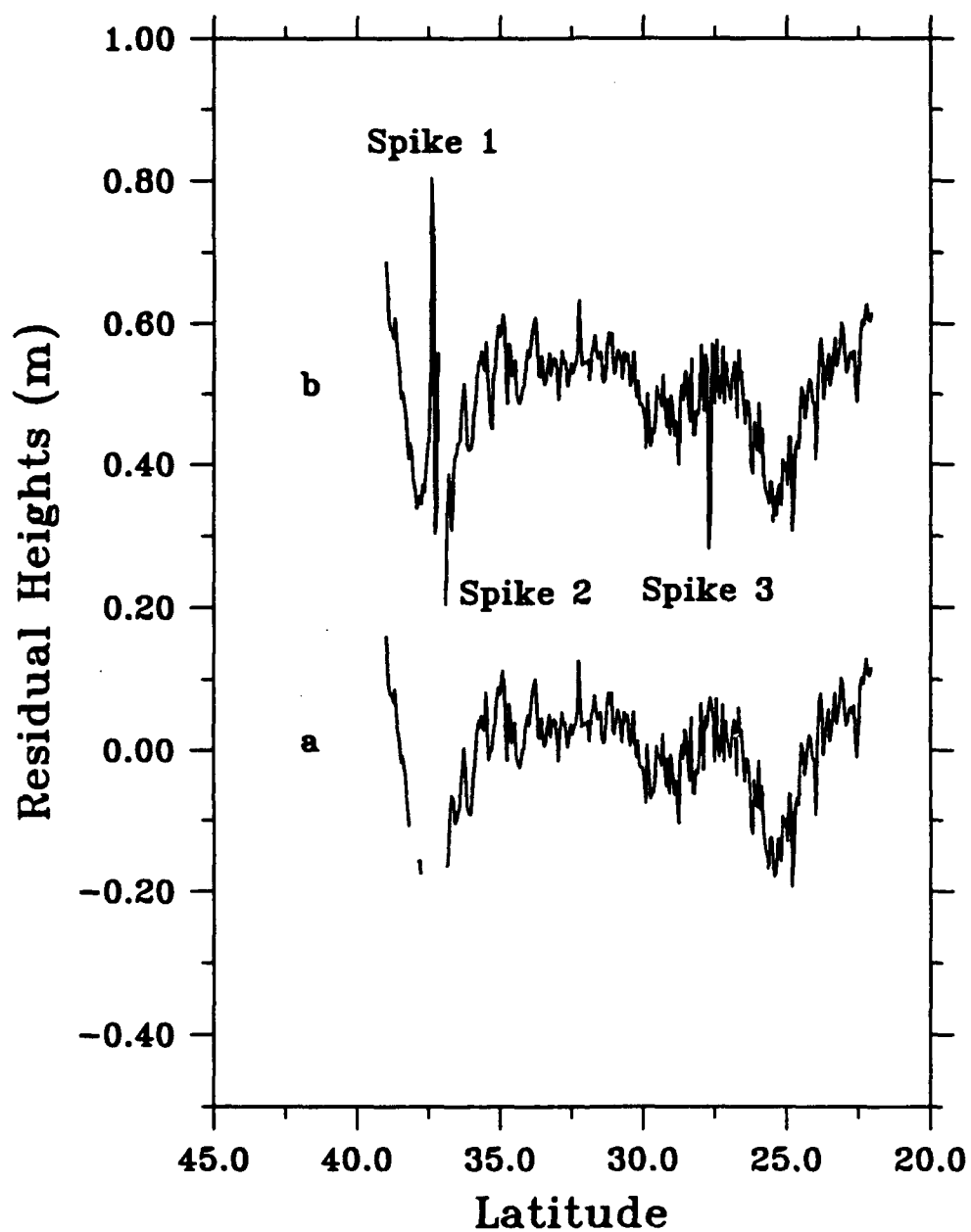


Figure 11: An example of the effect data spikes have on the residual for orbit c022.a160 over the Gulf Stream. Line a results from the default parameters and b results from 3.3 second data gaps, 9 fit points and 0.50 meter tolerance.

5.1.18 g_which

This program is designed to return all orbit numbers that cross within a specified latitude/longitude box. The arguments given to the program are the minimum and maximum latitudes and the minimum and maximum longitudes. To find all the orbits which cross a box 22° N to 48° N and 284° E to 316° E, the following command would be used:

```
g_which 22 48 284 316
```

With the following printout:

```
{a001,a002,d010,d011,a015,a016,d025,a030,a031,d039,d040,a044,  
a045,d053,d054,a059,d068,a073,a074,d082,d083,a087,a088,d096,  
d097,a102,d111,d112,a116,a117,d125,d126,a130,a131,d139,d140,  
a145,a146,d154,d155,a159,a160,d168,d169,a173,a174,d182,d183,  
a188,a189,d197,d198,a202,a203,d211,d212,a216,a217,d225,d226,  
a231,a232,d240,d241}
```

If only a single latitude/longitude point is given, the program finds the closest ascending and descending track and prints that:

```
g_which 30 280  
d083,a103
```

5.2 SSMI Programs

A list of available SSMI analysis programs is given in table 9 with a brief synopsis. More detailed descriptions are given below.

| List of SSMI programs | |
|-----------------------|--|
| Program | Description |
| s_ext | Extracts one or more parameters and converts to SI units |
| s_region | Separates collocated SSMI records in sequential orbits in a specified region |

Table 9:

5.2.1 s_ext

This program is similar to program *g_ext* except that it is designed to work on the SSMI data record. Usage is similar to *g_ext*. To extract the latitude, longitude and SSMI water vapor correction, the following command would be given:

```
%s_ext l L cws < s000.a002 > s000.a002asc
```

The complete list of abbreviations is given in table 10 and in the manual page in appendix A. A comparison between the water vapor corrections given in the GEOSAT GDR for a section of c015.a045 is given in figure 12.

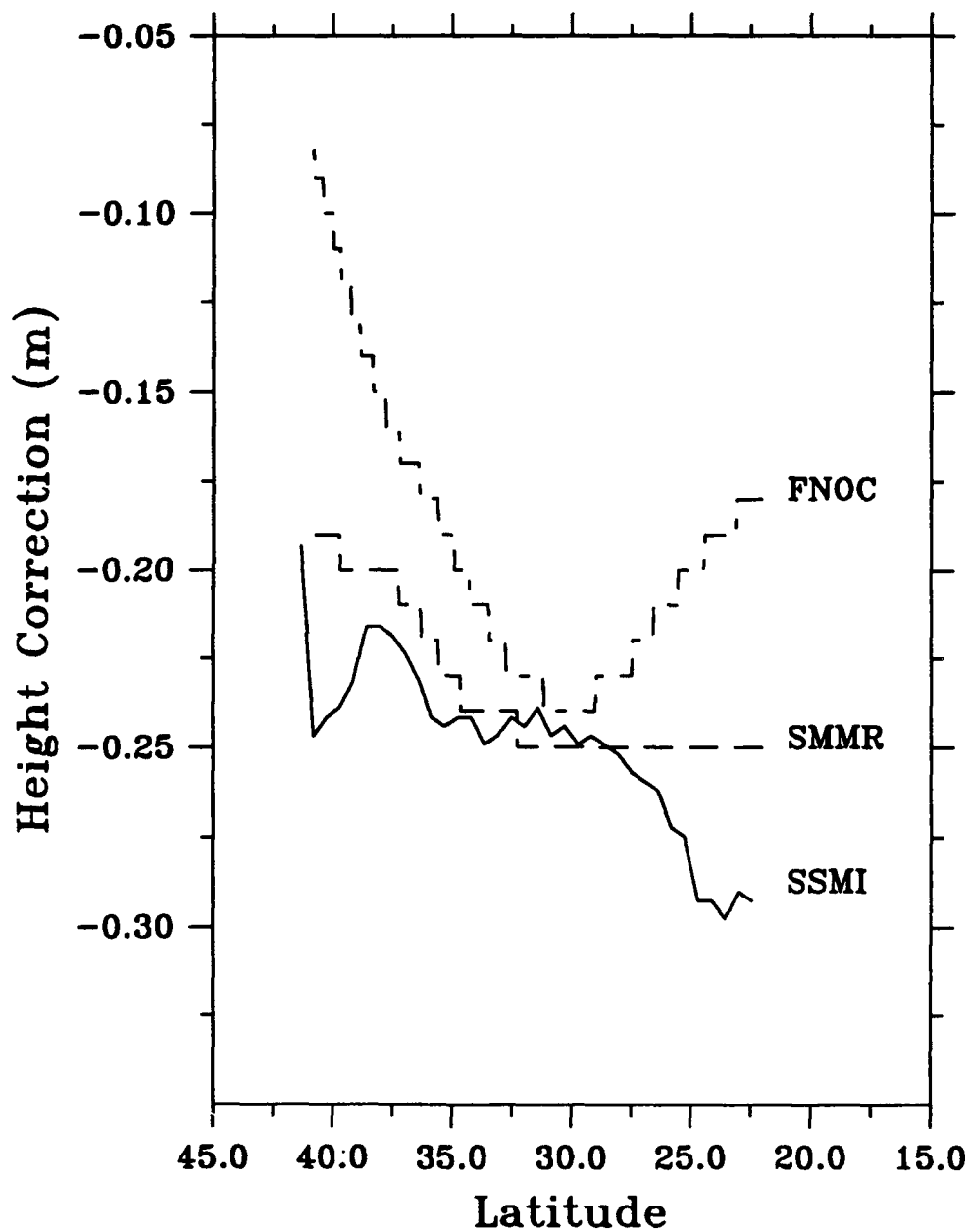


Figure 12: A comparison of the water vapor corrections from GEOSAT GDR and SSMI

| Abbreviation | Description |
|--------------|---|
| t | time in seconds since equator crossing of orbit c000.a000 |
| l | latitude in degrees |
| L | east longitude in degrees |
| fl | flag indicating data characteristic |
| | 1 - Over ocean |
| | 2 - No orbit altitude information |
| | 3 - Over land |
| | 4 - Over ice |
| ws | wind speed in ms^{-1} |
| vp | columnar water vapor in $kg\ m^{-2}$ |
| cl | columnar cloud vapor in $kg\ m^{-2}$ |
| rn | rain rate in $mm\ hr^{-1}$ |
| cws | SSMI correction for water vapor in meters |

Table 10: Description of variables for program s_ext

5.2.2 s_region

This program is similar to *g_region* except that it is designed to extract regions from SSMI data records. The orbits are numbered exactly the same as in *g_region*. The output cycles are also named the same except that the cycle numbers are preceded by an "s" instead of a "c". The program takes the first five arguments from *g_region*. To extract the area shown in figure 7, the following command would be given:

```
%s_region 1 22.0 48.0 284.0 316.0 < raw_ssmi
```

The output file named *s000.a002* would correspond to the GEOSAT file *c000.a002*.

5.3 Subroutines

A list of the subroutines developed for this project is given below with a brief synopsis of each routine.

5.3.1 geo_cyc_orb

This subroutine returns a cycle and orbit number for a given time. The subroutine is called:

```
geo_cyc_orb(time, &cyc, &orb)
```

where *time* is double precision and *cyc* and *orb* are integers. This can be used by any program that needs to know the cycle and orbit number for a given record, by passing the time variable in that record.

5.3.2 geo_error

This is a subroutine that is called to print out common error messages. The subroutine is called:

```
geo_error(num, str)
```

where *num* is the number of the error to print and *str* is the name of the program calling *geo_error*. The current messages are:

| Number | Message |
|--------|---------------------|
| 0 | Unrecoverable error |
| 1 | c???.[ad]??? |
| 2 | Error reading file |
| 3 | Error writing file |

5.3.3 *geo_mask*

This subroutine reads the UNIX environment variable **GMASK** if it is available and converts it to an integer. **GMASK** is used to indicate to various programs which GDR flags should be checked and which flags should be ignored. See section 5.1.1 and A for more details on the use of **GMASK**. The subroutine is called:

`geo_mask(&mask, &valid)`

where *mask* and *valid* are short (16-bit) integers. *Mask* is returned with its bits set to 1 for each 1 in **GMASK**. *Valid* is returned with its bits set to 1 for each 0 or 1 in **GMASK**. See section 5.1.1 and A for more details on the use of **GMASK**.

5.3.4 *geo_which*

This subroutine performs the same function as the program *g_which*. It can be used by any program that needs to determine which orbit numbers fall within a given latitude-longitude box. The subroutine is called:

`geo_which(min_lat, max_lat, min_lon, max_lon, a, d)`

where *min_lat*, *max_lat*, *min_lon* and *max_lon* are the boundaries of the region, *a* and *d* are unsigned character arrays that are returned. The arrays *a* and *d* have 244 elements, one for each orbit. Each will be returned with a 1 in the element that corresponds to an orbit that passes through the specified box. Otherwise, the program returns a 0 in that element. Thus, if orbit *a002* passes through the given region, *a*[2] = 1.

6 Repeat Orbit Analysis

The programs described in section 5 were written to facilitate repeat orbit analysis. This section describes how these programs were used in conjunction to analyze a section of North Atlantic covering the Gulf Stream. The area of interest, 22° N to 48° N, 284° E to 316° E, is shown in figure 7, and is restricted to the ascending orbits. The analysis could also be performed for the descending orbits in a similar manner. The shell script in appendix C shows how these programs may be used together.

To perform a repeat analysis, the GDRs must first be removed from the data tape with the following command:

```
%dd if=/dev/rmt8 ibs=16380 files=34 | g-region 1 22.0 48.0 284.0 316.0 2 88
```

This extracts all the ascending and descending orbits within the specified region and places them in the current directory following the naming convention described in section 4. For the first GEOSAT tape, the directory listing is as follows:

| | | | | | | |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| c000.a001 | c000.a145 | c000.d053 | c000.d197 | c001.a074 | c001.a216 | c001.d126 |
| c000.a002 | c000.a146 | c000.d068 | c000.d198 | c001.a087 | c001.a217 | c001.d139 |
| c000.a015 | c000.a159 | c000.d082 | c000.d211 | c001.a088 | c001.a232 | c001.d140 |
| c000.a016 | c000.a160 | c000.d083 | c000.d212 | c001.a102 | c001.d010 | c001.d154 |
| c000.a030 | c000.a173 | c000.d096 | c000.d225 | c001.a116 | c001.d011 | c001.d155 |
| c000.a031 | c000.a174 | c000.d097 | c000.d226 | c001.a117 | c001.d025 | c001.d168 |
| c000.a044 | c000.a188 | c000.d111 | c000.d240 | c001.a130 | c001.d039 | c001.d169 |
| c000.a045 | c000.a189 | c000.d112 | c000.d241 | c001.a131 | c001.d040 | c001.d182 |
| c000.a059 | c000.a202 | c000.d125 | c001.a001 | c001.a145 | c001.d053 | c001.d183 |
| c000.a073 | c000.a203 | c000.d126 | c001.a002 | c001.a146 | c001.d054 | c001.d197 |
| c000.a074 | c000.a216 | c000.d139 | c001.a015 | c001.a159 | c001.d068 | c001.d198 |
| c000.a087 | c000.a217 | c000.d140 | c001.a016 | c001.a160 | c001.d082 | c001.d211 |
| c000.a088 | c000.a231 | c000.d154 | c001.a030 | c001.a173 | c001.d083 | c001.d212 |
| c000.a102 | c000.a232 | c000.d155 | c001.a031 | c001.a174 | c001.d096 | c001.d225 |
| c000.a116 | c000.d010 | c000.d168 | c001.a044 | c001.a188 | c001.d097 | c001.d226 |
| c000.a117 | c000.d025 | c000.d169 | c001.a045 | c001.a189 | c001.d111 | c001.d240 |
| c000.a130 | c000.d039 | c000.d182 | c001.a059 | c001.a202 | c001.d112 | c001.d241 |
| c000.a131 | c000.d040 | c000.d183 | c001.a073 | c001.a203 | c001.d125 | |

These files should then be moved into subdirectories named with the cycle number:

| | | | | | | | | | | |
|------|------|------|------|------|------|------|------|------|------|------|
| c000 | c005 | c010 | c015 | c020 | c025 | c030 | c035 | c040 | c045 | c050 |
| c001 | c006 | c011 | c016 | c021 | c026 | c031 | c036 | c041 | c046 | c051 |
| c002 | c007 | c012 | c017 | c022 | c027 | c032 | c037 | c042 | c047 | c052 |
| c003 | c008 | c013 | c018 | c023 | c028 | c033 | c038 | c043 | c048 | c053 |
| c004 | c009 | c014 | c019 | c024 | c029 | c034 | c039 | c044 | c049 | |

The GDRs must then be cleaned, corrected and regridded. Data anomalies such as spikes or gaps should also be removed.

Following the shell script step-by-step, the GDRs are first cleaned and corrected using default values and stored in a temporary file *tmp*:

```
cat c000/c000.a002 | g-clean1 | g-correct | g-clean2 >! tmp
```

This temporary file is then cleaned of any remaining spikes and splined to a uniform grid and stored as a new file:

```
(cat tmp | g-spike | g-spline 1 22 48 3.3 0.97992165 > c000/c000.a002c)
```

These two steps are repeated using the *foreach* command for each cycle until all cycles are processed. Then the repeat analysis is performed:

```
g-repeat c*/c*.a002c > means/mean.a002c
```

G-repeat automatically writes the residual files to the same directory as the input clean files and appends an *_r* to the end of the filename. The output file *mean.a002c* contains the geoid and variability of the orbit *a002*.

Acknowledgements

The authors would like to thank Dr. Kathryn Kelly for her advice on algorithm development, Dr. Robert Beardsley for his support of this project and Debbie Barber for her suggestions on the text. Funding for this project was provided by the Office of Naval Research under contract number N00014-86-k-0751.

References

- [1] J. Hollinger, R. Lo, G. Poe, R. Savage, and J. Pierce. *Special Sensor Microwave/Imager User's Guide*. Technical Report, Naval Research Laboratory, Washington, D.C., 1987.
- [2] Robert E. Cheney, Bruce C. Douglas, Russell W. Agreen, Laury Miller, David L. Porter, and Nancy S. Doyle. *Geosat Altimeter Geophysical Data Record User Handbook*. Technical Report NOS NGS-46, National Oceanographic and Atmospheric Administration, July 1987.
- [3] F. J. Wentz. *User's Manual: Collocated GEOSAT - SSM/I tape*. Technical Report RSS 083189, Remote Sensing Systems, Santa Rosa, CA, 1989.
- [4] Michael Caruso and Chris Dunn. *Satellite Data Processing System (SDPS) Users Manual V1.0*. Technical Report WHOI89-13, Woods Hole Oceanographic Institution, Woods Hole, MA, 1989.

A Manual Pages

This section contains the UNIX style manual pages for each of the programs and sub-routines listed in sections 5.1, 5.2 and 5.3.

NAME

geosat - Programs and subroutines for processing GEOSAT GDR files.

DESCRIPTION

This manual page describes the various programs available for processing GEOSAT GDR files. These programs were developed at the Woods Hole Oceanographic Institution to simplify the handling of raw NODC data tapes. These programs were designed to run under the 4.2/4.3 BSD UNIX operating system.

These programs were designed to take full advantage of existing UNIX commands as well as the UNIX file system.

ORBIT INFORMATION**LABELING**

The original data from NODC comes in 17 files that contain 14 or 15 complete orbits each. These 17 files make a complete repeat cycle. To facilitate data handling, these files are broken up into individual orbits which are further broken up to an ascending component and a descending component. The ascending and descending components are broken at the most northern and southern excursion of the satellite. The resulting files are named:

cnnn.dmmm for descending orbit *mmm* of repeat cycle *nnn*

cnnn.ammm for ascending orbit *mmm* of repeat cycle *nnn*

By convention, orbit numbers *mmm* and cycle numbers *nnn* begin with 000 for the first orbit and cycle on the first data tape sent out from NOAA which begins on November 8, 1986. Also, by convention, the ascending orbit follows the descending orbit. The last point of an ascending or descending orbit is the most northern or most southern point of that orbit.

PARAMETERS

The following parameters were used in the various programs listed below. These parameters were computed by a least squares fit over cycles 000 and 001.

| | | |
|--|-------------|------|
| orbital period PERIOD | 6037.5515 | sec |
| repeat cycle 244*PERIOD | 17.0504 | days |
| distance between adjacent crossings 360/244 | 1.4754 | deg |
| distance between successive crossings 17*360/244 | -25.0820 | deg |
| time of the equator crossing of c000.a000 | 58407697.82 | sec |
| longitude of the equator crossing of c000.a000 | 356.58783 | deg |

LIST OF PROGRAMS

| Name | Manual Page | Description |
|--------------|-----------------|---|
| g_ext | g_ext(1) | Extracts GDR variables in ASCII format |
| g_clean1 | g_clean1(1) | Removes obviously bad data from GDRs |
| g_clean2 | g_clean2(1) | Removes bad data from corrected GDRs |
| g_compress | g_compress(1) | Compress GDRs to 18 bytes |
| g_correct | g_correct(1) | Applies suggested correction to GDRs |
| g_crossnum | g_crossnum(1) | Finds equator crossing of given orbit |
| g_date | g_date(1) | Prints start and end date for GDR segment |
| g_date2 | g_date2(1) | Prints start and end date for given orbit and cycle |
| g_image | g_image(1) | Creates an bitmap image of GEOSAT data |
| g_interp | g_interp(1) | Interpolates to an even grid |
| g_print | g_print(1) | Decodes GDRs to ASCII format |
| g_region | g_region(1) | Extracts a region from continuous GDRs |
| g_repeat | g_repeat(1) | Performs repeat analysis on GDRs |
| g_seporb | g_seporb(1) | Separates continuous GDRs into asc & desc orbits |
| g_spike | g_spike(1) | Removes spikes from GDRs |
| g_spline | g_spline(1) | Splines GDRs to an even grid |
| g_uncompress | g_uncompress(1) | Uncompresses 18 byte data record |
| g_which | g_which(1) | Prints orbit numbers in a given box |

LIST OF SUBROUTINES

| Name | Description |
|-------------|---|
| geo_error | Prints error messages to standard output. |
| geo_cyc_orb | Returns cycle and orbit number for given GDR |
| geo_mask | Reads environment variable GMASK |
| geo_which | Returns arrays of orbits which cross an area. |

BUGS

Please report bugs to mcaruso@aqua.whoi.edu or pierre@io.soest.hawaii.edu

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NAME

g_clean1 - cleans GEOSAT GDR data

SYNOPSIS

g_clean1

DESCRIPTION

This program reads a binary GEOSAT file from *stdin* and removes data records with one or more bad data flags, or if any of the following variables are set:

| Variable | Description | Bad value |
|----------|-------------------------------------|-----------|
| ha | sea surface height above ellipsoid | 32767cm |
| sha | sigma ha | >30cm |
| so | sigma naught (backscatter coef) | >35dB |
| cet | correction for earth tide | 32767mm |
| cot | correction for ocean tide | 32767mm |
| cwf | correction for wet troposphere fnoc | 32767mm |
| cdf | correction for dry troposphere | 32767mm |
| ci | correction for ionosphere | 32767mm |

The user may also specify which data flags are to be used. A record will be skipped if the flag bits do not match the mask given by the environment variable **GMASK**. This variable should contain a string of characters describing the flag bits from 0 to 15 from left to right. A "-" means ignore this bit; a "0" means skip this record if this bit is not 0; a "1" means skip this record if this bit is not 1. If the variable **GMASK** is not set, the default mask "1 - - - - - 0 - - - - - 0 0" is assumed, i.e., the data over land is not printed. Examples of possible masks:

setenv GMASK 1 1 - - 0 0 0 0 - - - - - 0 0

will skip records over land and shallow water and for which the VATT is dubious;

setenv GMASK 0 0 - - - - - 0 - - - - - 0 0

will print the data over land only.

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SEE ALSO

geosat(1)

NAME

g_clean2 - cleans GEOSAT GDR data

SYNOPSIS

g_clean2

DESCRIPTION

This program reads a binary GEOSAT file from *stdin* and removes data records with sea surface heights greater than 10,000 cm or less than -14,000 cm. Output is in GEOSAT GDR format. The program assumes that corrections have been applied to the data previously.

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SEE ALSO

geosat(1) **g_correct(1)**

NAME

g_compress, g_uncompress - compresses/uncompresses special 18-byte data record

SYNOPSIS

g_compress
g_uncompress

DESCRIPTION

These programs were designed to compress and uncompress a standard GDR to 18 bytes by reducing precision and removing less important variables. The format of the 18-byte record is given below.

| | | | |
|--------------|---------------------|-------------|------------------------|
| Time | ms | 0 to 1.47E9 | long int (4-bytes) |
| Height | cm | 0 to 32767 | short int (2-bytes) |
| Cycle | | 0... | char (1-byte) |
| Latitude | 10 ⁴ Deg | 0 to 18E5 | unsigned int (3-bytes) |
| Longitude | 10 ⁴ Deg | 0 to 36E5 | unsigned int (3-bytes) |
| Sigma Height | cm | 0 to 255 | unsigned char (1-byte) |
| SWH | 5cm | 0 to 255 | unsigned char (1-byte) |
| s_naught | 0.1dB | 0 to 255 | unsigned char (1-byte) |
| Flags | | | char (1-byte) |
| Ocean Tide | cm | -128 to 128 | char (1-byte) |

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SEE ALSO

geosat(1)

NAME

g-correct - corrects GEOSAT GDR data

SYNOPSIS

g-correct [*cot cet cwf cdf ci cib*]

DESCRIPTION

This program reads a binary GEOSAT file from *stdin* and applies the following correction to the sea surface height.

$$ha(\text{corrected}) = ha - cet - cot - cwf - cdf - ci - cib$$

where

$$cib = -9.948 * (p - 1013.3)$$

and

$$p = cdf / ((-2.277) * (1. + (0.0026 * \cos(2 * \text{latitude}))))$$

using the following variables from the GDR.

| Variable | Description |
|----------|-------------------------------------|
| ha | sea surface height above ellipsoid |
| cet | correction for earth tide |
| cot | correction for ocean tide |
| cwf | correction for wet troposphere fnoc |
| cdf | correction for dry troposphere |
| ci | correction for ionosphere |
| cib | correction for inverse barometer |

The program assumes that the input GDR has been previously cleaned up. The default is to apply all corrections. By selecting one or more of the option arguments, only those arguments given will be applied.

REFERENCE

Geosat Altimeter Geophysical Data Record User Handbook,
Cheney et al., NOAA Technical Memorandum NOS NGS-46, July 1987

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SEE ALSO

geosat(l) **g-clean1(l)**

NAME

#

g_crossnum - finds the orbit crossing for a sequential GEOSAT orbit

SYNOPSIS

g_crossnum [*orbit*]

DESCRIPTION

This program may be used in two ways. First, it can be called with an orbit number:

g_crossnum a002

Second, if no arguments are given, the program will read a GEOSAT GDR from *stdin*:

g_crossnum < c000.a002

The output is the approximate longitude of the orbit crossing at the equator. This is useful for comparing sequentially numbered orbits with orbits numbered by equatorial crossing.

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SEE ALSO

geosat(1)

NAME

g-date - prints the start and end date of GEOSAT GDR data

SYNOPSIS

g-date

DESCRIPTION

This program reads a binary GEOSAT file from *stdin* and prints the date and time of the first and last record in the file. The program also lists the Julian day, the year day and the day of the cycle.

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SEE ALSO

geosat(1) **g-date2(1)**

NAME

g_date2 - prints the start and end date of GEOSAT GDR data

SYNOPSIS

g_date2 *cycle orbit*

DESCRIPTION

This program reads the cycle and orbit number from the command line and prints the date and time of the first and last record of that orbit. The program also lists the Julian day, the year day and the day of the orbit.

AUTHORS

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SEE ALSO

geosat(1) **g_date(1)**

NAME

g_ext - extracts GEOSAT GDR data and prints variables in ASCII

SYNOPSIS

g_ext list

DESCRIPTION

This program reads a binary GEOSAT file from *stdin* and extracts the specified variables on *stdout*. The variable *list* may be a combination of one or more of the following variables, in any order separated by spaces:

| Variable | Description |
|----------|--|
| t | time in seconds since START.TIME |
| l | latitude in degrees |
| L | east longitude in degrees |
| ho | orbit height above ellipsoid in m |
| ha | sea surface height above ellipsoid in m |
| sha | sigma ha |
| hg | geoid height above ellipsoid in m |
| w | significant wave height |
| sw | sigma w |
| so | backscatter coefficient in 0.01 dB |
| ag | agc in 0.01 dB |
| sag | sigma ag |
| fl | masked flags |
| HA | land surface height offset above ellipsoid |
| cet | correction for earth tide in m |
| cot | correction for ocean tide in m |
| cwf | correction for wet troposphere fnoc |
| cws | correction for wet troposphere smmr |
| cdf | correction for dry troposphere |
| ci | correction for ionosphere |
| ba | attitude bias |
| bc | compression bias |
| att | attitude |
| cib | correction for inverse barometric effect |
| h | corrected sea surface height above ellipsoid |
| dh | corrected sea surface height above geoid |

A record will not be printed if any of the requested variables contains invalid data (32767).

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SEE ALSO

geosat(1)

NAME

g_image - Generates a bitmap image of GEOSAT GDR data

SYNOPSIS

g_image min_lat min_lon max_lat max_lon rows cols

DESCRIPTION

This program reads an ASCII file with the latitude, longitude and *z* value on one line from *stdin*. The program writes an SDPS floating point file to *stdout*. For information on converting this to a byte image see *sdps_ftb(1)*. The output file is an equirectangular image *rows* high by *columns* wide with coordinates from *min_lat* to *max_lat* and *min_lon* to *max_lon*.

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REFERENCE

Caruso, M. and C. Dunn, Satellite Data Processing System (SDPS) Users Manual V1.0, Woods Hole Oceanog. Inst. Tech. Rept., WHOI-89-13, 1989

SEE ALSO

geosat(1) *sdps(1)* *sdpsutil(1)* *sdps_ftb(1)*

NAME

g_interp - linearly interpolates the GEOSAT GDR data

SYNOPSIS

g_interp [dir min maz deltmaz timestep]

DESCRIPTION

This program reads a binary GEOSAT file from *stdin* and breaks the data into continuous segments where a gap is defined by a gap of *deltmaz* seconds between records. This program is used to regrid the GDRs to a consistent latitude-longitude grid. The algorithm was designed so that at least one point lies on the equator crossing and each successive point is *timestep* seconds from the previous point. The program will fill gaps with a calculated latitude and bad values (32767) for the longitude and height variables. Since not all orbits will be complete, the user also needs to specify a minimum and maximum latitude or longitude with *min* and *maz* as well as the direction of the boundary with *dir*. If *dir* is 1, the record is filled between a minimum and maximum latitude and if *dir* is 2, the record is filled between the minimum and maximum longitude. The program assumes that corrections have been applied to the data previously and the data is free of abnormal values that appear as spikes.

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SEE ALSO

geosat(1) *g_correct(1)* *g_spike(1)* *g_spline(1)*

NAME

g-print - Decodes GEOSAT GDR records in a lengthy format

SYNOPSIS

g-print

DESCRIPTION

This program takes GEOSAT GDR files and prints in a lengthy ASCII format. Each parameter is printed in its raw format with an identifier to *stdout*. Of special note is the data flags parameter. The flags are ordered as follows:

FEDCBA9876543210

where 0 is the zeroth flag bit and F is the fifteenth flag bit as listed in the GEOSAT Altimeter GDR User Handbook.

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SEE ALSO

geosat(1)

NAME

g_region - Extracts a specified region from a GEOSAT GDR data set

SYNOPSIS

g_region *dir min_lat max_lat min_lon max_lon [orb#]*

DESCRIPTION

This program reads a binary GEOSAT file from *stdin*, extracts a specified region and separates the data into ascending and descending orbits that comply with the naming conventions described in *geosat(1)* manual page. This program finds the data that fall within the latitude-longitude box given by the parameters *min_lat*, *max_lat*, *min_lon*, *max_lon*. In order to maintain reasonable orbit lengths, the program will clip the orbits with either a constant latitude boundary, or a constant longitude boundary. Therefore, orbits that would normally be clipped in the corners, are extended to either the constant latitude or longitude boundary. The constant direction is chosen with the parameter *dir*. If *dir* is 1, the program extracts all data from that orbit that is between *min_lat* and *max_lat*. If *dir* is 2, the program extracts all data that is between *min_lon* and *max_lon*. If the optional orbit numbers are given, only those orbits that fall within the given box are extracted.

This program can be used to extract data directly from the NODC data tapes:

```
dd if=/dev/rmt8 ibs=16380 files=34 | g_region 1 10.0 30.0 280.0 300.0
```

BUGS

This program should only be used on complete orbits. It does not work on files that have already been extracted using *g_region* or *g_seporb*.

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SEE ALSO

geosat(1) *g_seporb(1)*

NAME

g_repeat - performs a repeat analysis on GEOSAT GDR data

SYNOPSIS

g_repeat c???.azzz

DESCRIPTION

This program reads a binary GEOSAT file from each of the file names on the command line. The mean sea surface height is calculated for each point along the track and subtracted from each cycle. A quadratic polynomial is fit to the difference and subtracted from each cycle. The variance of the remainder is then used to calculate a new quadratic fit. This polynomial is then removed from the original sea surface height as an orbit error. The residual height for each cycle is written to a file with the record number, the latitude, the longitude, the residual heights along with the two quadratic polynomial. Also the statistics for each point are printed to standard output. This file contains the record number, the latitude, the longitude, the mean and variance of the corrected heights, the sum of the squared heights and the number of points used for the statistics of each record. All heights are given in meters. The program assumes that corrections have been applied to the data previously and the data has been splined to a uniform latitude-longitude grid.

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SEE ALSO

geosat(l) g.correct(l) g.spline(l) g.repeats(l)

NAME

g_repeats - performs a repeat analysis on GEOSAT GDR data

SYNOPSIS

g_repeats c???azza

DESCRIPTION

This program reads a binary GEOSAT file from each of the file names on the command line. The mean sea surface height is calculated for each point along the track and subtracted from each cycle. A sinusoidal is fit to the difference and subtracted from each cycle. The variance of the remainder is then used to calculate a new sinusoidal fit. This polynomial is then removed from the original sea surface height as an orbit error. The residual height for each cycle is written to a file with the record number, the latitude, the longitude, the residual heights along with the two sine results. Also the statistics for each point are printed to standard output. This file contains the record number, the latitude, the longitude, the mean and variance of the corrected heights, the sum of the squared heights and the number of points used for the statistics of each record. All heights are given in meters. The program assumes that corrections have been applied to the data previously and the data has been splined to a uniform latitude-longitude grid.

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SEE ALSO

geosat(l) g_correct(l) g_spline(l) g_repeat(l)

NAME

g_seporb - separates raw GEOSAT GDR data into ascending and descending orbits

SYNOPSIS

g_seporb

DESCRIPTION

This program reads a binary GEOSAT file from *stdin* and separates the data into ascending and descending orbits that comply with the naming conventions described in *geosat(1)* manual page. This program can be used to separate data directly from the NODC data tapes:

```
dd if=/dev/rmt8 ibs=16380 files=34 | g_seporb
```

BUGS

Input is expected to have at least two valid GDRs.

AUTHOR

Mike Caruso
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Woods Hole, MA 02543

SEE ALSO

geosat(1) *g_region(1)*

NAME

g_spike - removes spikes from GEOSAT GDR data

SYNOPSIS

g_spike [*deltmax neighbors outlier*]

DESCRIPTION

This program reads a binary GEOSAT file from *stdin* and removes data records that appear as spikes in the sea surface height. The program assumes that corrections have been applied to the data previously. *Deltmax* is the amount of time that constitutes a gap between continuous segments (default is 3.3 seconds), *neighbors* is the number of points to use for least squares fit to a quadratic polynomial (default is 13 points) and *outlier* is the maximum acceptable deviation from the least squares fit (default is 0.20 meters)

AUTHOR

Mike Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

SEE ALSO

geosat(1) **g-correct(1)**

NAME

g-spline - splines the GEOSAT GDR data

SYNOPSIS

g-spline [dir min maz deltmaz timestep]

DESCRIPTION

This program reads a binary GEOSAT file from *stdin* and breaks the data into continuous segments where a gap is defined by *deltmaz* seconds between records. This program is used to regrid the GDRs to a consistent latitude-longitude grid. The algorithm was designed so that at least one point lies on the equator crossing and each successive point is *timestep* seconds from the previous point. The program will fill gaps with a calculated latitude and bad values (32767) for the longitude and height variables. Since not all orbits will be complete, the user also needs to specify a minimum and maximum latitude or longitude with *min* and *maz* and the direction of the boundary with *dir*. If *dir* is 1, the record is filled between a minimum and maximum latitude and if *dir* is 2, the record is filled between the minimum and maximum longitude. The program assumes that corrections have been applied to the data previously and the data is free of abnormal values that appear as spikes.

AUTHOR

Mike Caruso
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Woods Hole, MA 02543

SEE ALSO

geosat(l) g-correct(l) g-spike(l) g-interp(l)

NAME

g-which - Prints **GEOSAT** orbit numbers from a specified lat/lon box

SYNOPSIS

g-which *min_lat maz_lat min_lon maz_lon*

DESCRIPTION

This program reads the minimum and maximum latitudes and minimum and maximum longitudes from the command line and prints the orbit numbers contained in the box. The orbits are printed within curly braces, separated by commas and may be used in a set of pipes.

```
cat c000.'g-which 30 45 280 300' | g_ext l L
```

If only two arguments are given to the program, they are assumed to be a point and the nearest ascending and descending orbits are given.

AUTHORS

Mike Caruso
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Pierre Flament
Oceanography Department
University of Hawaii
Honolulu, HI 96822

SEE ALSO

geosat(1)

NAME

s_ext - extracts SSMI data and prints variables in ASCII

SYNOPSIS

s_ext list

DESCRIPTION

This program reads a binary SSMI file from *stdin* and extracts the specified variables on *stdout*. *List* may be a combination of one or more of the following variables, in any order separated by spaces:

| Variable | Description |
|----------|--------------------------------------|
| t | time in seconds since START.TIME |
| l | latitude in degrees |
| L | east longitude in degrees |
| f | flag indicating data characteristics |
| | 0 - Over ocean |
| | 1 - No orbit altitude information |
| | 2 - Over land |
| | 3 - Over sea ice |
| ws | Wind Speed |
| vp | columnar water vapor |
| cl | columnar cloud water |
| rn | rain rate |
| cws | SSMI correction for water vapor |

A record will not be printed if any of the requested variables contains invalid data (32767).

AUTHORS

Pierre Flament
Mimi Baker
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Honolulu, HI 96822

SEE ALSO

geosat(1)

NAME

s_region - Extracts a specified region from a SSMI data set

SYNOPSIS

s_region *dir min_lat maz_lat min_lon maz_lon*

DESCRIPTION

This program reads a binary SSMI file from *stdin*, extracts a specified region and separates the data into ascending and descending orbits that comply with the naming conventions described in *geosat(1)* manual page. This program finds the data that fall within the latitude-longitude box given by the parameters *min_lat maz_lat min_lon maz_lon*. In order to maintain reasonable orbit lengths, the program will clip the orbits with either a constant latitude boundary, or a constant longitude boundary. Therefore, orbits that would normally be clipped in the corners, are extended to either the constant latitude or longitude boundary. The constant direction is chosen with the parameter *dir*. If *dir* is 1, the program extracts all data from that orbit that is between *min_lat* and *maz_lat*. If *dir* is 2, the program extracts all data that is between *min_lon* and *maz_lon*.

This program can be used to extract data directly from the data tapes:

```
dd if=/dev/rmt8 ibs=14400 | s_region 1 10.0 30.0 280.0 300.0
```

AUTHORS

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Honolulu, HI 96822

Mike Caruso
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Woods Hole, MA 02543

SEE ALSO

geosat(1) *g_region(1)* *g_seporb(1)*

B Program Listings

This section contains listing of all programs and subroutines discussed in sections 5.1, 5.2 and 5.3. Programs are listed alphabetically and subroutines follow the programs.

Program g_clean1.c

/*

@(#)g_clean1.c 1.5 6/13/90
Program g_clean1.c

Written by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Purpose:

This is the first step in cleaning up GEOSAT data.
This program will remove bad data points as specified
by the shell variable GMASK (See users manual) as well
as points with sigma height > 30 cm and sigma naught
> 35 Db.

Method:

Reads raw GEOSAT GDRs from standard input and deletes any
records that are not within specified parameters. Output
is in GDR format.

Usage:

The GEOSAT GDR is read from standard input.

cat c000.a002 | g_clean1 > c000.a002c

will remove all bad records from the GDR in c000.a002.

Input:

Stdin Raw GEOSAT GDRs

Output:

Stdout: Clean GEOSAT GDRs

Subroutines Required:

geo_error Prints errors to standard error
geo_mask Gets mask variable GMASK

References:

```

*/
# include <math.h>
# include <stdio.h>
# include <string.h>
# include "geos.h"

#define SHBAD 30.0          /* Value for bad sigma height */
#define SNBAD 3500.0       /* Value for bad sigma naught */
#define CHECKFL 12415      /* Used to get rid of check sum flags */

int i,j;
int bad;
int fl_bad;
short int msk, valid;

union
{
    struct flags fl;
    short int flagint;
} cl_flags;          /* To allow bit operations on flags */

main (argc,argv)
    int argc;
    char *argv[];

{
    /*
    Set counters to zero...
    */

    int    good_count      = 0;
    int    m_h_count       = 0;
    int    s_tide_count     = 0;
    int    o_tide_count     = 0;
    int    w_fnoc_count     = 0;
    int    d_fnoc_count     = 0;
    int    iono_count       = 0;
    int    s_h_count        = 0;
    int    s_nght_count     = 0;
    int    flag_count       = 0;
    int    tot_count        = 0;

    /*
    Check for arguments...
    */

    if (argc != 1)
    {
        fprintf(stderr,"Usage: %s < filein > filout\n",argv[0]);
        exit(1);
    }
}

```

```

/* get from the environment which bits of the flags should be masked
   and which values constitute a valid frame */

geo_mask(&msh,&valid);

/*
   Loop over all points in input file...
*/

while (fread((char*)&fr,1,REC_LEN,stdin)==REC_LEN)
{
    /* get rid of checksum flags 0011000001111111 */

    cl_flags.fl = fr.fl;

    cl_flags.flagint &= CHECKFL;

    /* set bad to false if mask of the data flags */
    /* is not equal to valid mask */

    bad = (cl_flags.flagint & msk) != valid;
    if(bad) fl_bad = BAD;

    /*
       Check all records for any bad data. Don't check Time,
       lat or lon. Reject if ha at that point is bad, or if cet,
       cot, cwf, cdf or ci is bad.
    */

    bad = bad
        || (fr.m_h == BAD
            || fr.s_tide == BAD
            || fr.o_tide == BAD
            || fr.w_fnoc == BAD
            || fr.d_fnoc == BAD
            || fr.iono == BAD
            || fr.s_h > SHBAD
            || fr.s_nght > SNBAD);

    if (bad)
    {
        if (fr.m_h == BAD) m_h_count += 1;
        if (fr.s_tide == BAD) s_tide_count += 1;
        if (fr.o_tide == BAD) o_tide_count += 1;
        if (fr.w_fnoc == BAD) w_fnoc_count += 1;
        if (fr.d_fnoc == BAD) d_fnoc_count += 1;
        if (fr.iono == BAD) iono_count += 1;
        if (fr.s_h > SHBAD) s_h_count += 1;
        if (fr.s_nght > SNBAD) s_nght_count += 1;
        if (fl_bad == BAD) flag_count += 1;
        tot_count += 1;
    }
}

```

```

    }
    fl_bad = 0;
    if (bad) continue;      /* If bad skip print and get next point. */

    /*
     Write out good data records.
    */

    if (fwrite((char *)&r, 1, REC_LEN, stdout) != REC_LEN)
    {
        geo_error(3,argv[0]);
        exit(3);
    }
    good_count += 1;
}

/*
Write out statistics on rejected points to standard output...
*/

fprintf(stderr,"%s: Valid points:\t%8d\n",argv[0],good_count);
fprintf(stderr,"\tRejected points:%8d\n",tot_count);
fprintf(stderr,"\tHeight:\t\t%8d\n",m_h_count);
fprintf(stderr,"\tSolid Tide:\t%8d\n",s_tide_count);
fprintf(stderr,"\tOcean Tide:\t%8d\n",o_tide_count);
fprintf(stderr,"\tWet FNOC:\t%8d\n",w_fnoc_count);
fprintf(stderr,"\tDry FNOC:\t%8d\n",d_fnoc_count);
fprintf(stderr,"\tIono:\t\t%8d\n",iono_count);
fprintf(stderr,"\tSigma Height:\t%8d\n",s_h_count);
fprintf(stderr,"\tSigma Naught:\t%8d\n",s_nght_count);
fprintf(stderr,"\tFlags:\t\t%8d\n",flag_count);
}

```


Program g_clean2.c

/*

@(#)g_clean2.c 1.3 12/15/89

Program g_clean2.c

Written by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Modifications:

12-15-89 MC now also prints total number of points rejected.

Purpose:

This program will clean a GEOSAT GDR by removing records with heights greater than 10,000 cm and less than -14,000 cm.

Method:

Reads raw GEOSAT GDRs from standard input and checks height. Does not check for validity of input and assumes input data has had corrections applied. Output is in GDR format.

Usage:

The GEOSAT GDR is read from standard input.

cat c000.a002 | g_clean2 > c000.a002c

will clean all bad data records from the GDR in c000.a002.

Input:

Stdin Raw GEOSAT GDRs

Output:

Stdout: Corrects GEOSAT GDRs

Subroutines Required:

geo_error Prints error messages.

References:

```
-----

*/
# include <math.h>
# include <stdio.h>
# include <string.h>
# include "geos.h"

#define MIN_HEIGHT -14000
#define MAX_HEIGHT 10000

main (argc,argv)
{
    int argc;
    char *argv[];

    int min_count = 0;
    int max_count = 0;
    int tot_count = 0;

    if (argc != 1)
    {
        fprintf(stderr,"Usage: %s < filein > fileout\n",argv[0]);
        exit(1);
    }

    while (fread((char*)&fr,1,REC_LEN,stdin)==REC_LEN)
    {
        /*
        Check GDR heights here.
        */

        if ((fr.m_h < MAX_HEIGHT) || (fr.m_h > MIN_HEIGHT))
        {
            /*
            Write out good data records.
            */

            if (fwrite((char *)&fr, 1, REC_LEN, stdout) != REC_LEN)
            {
                geo_error(3,argv[0]);
                exit(3);
            }
        }

        else
        {
            if (fr.m_h > MAX_HEIGHT) max_count += 1;
            else if (fr.m_h < MIN_HEIGHT) min_count += 1;

            if ((fr.m_h > MAX_HEIGHT) || (fr.m_h < MIN_HEIGHT)) tot_count += 1;
        }
    }
}
```

```

    }

}
/*
  Print rejection numbers...
*/
fprintf(stderr,"%s: Rejected points:%6d\n", argv[0], tot_count);
fprintf(stderr,"\tMaximum Height:\t%8d\n", max_count);
fprintf(stderr,"\tMinimum Height:\t%8d\n\n", min_count);
}

```

Program g_compress.c

/*

0(#)g_compress.c 1.2 6/13/90

Written by:

Pierre Flament
Oceanography Department
University of Hawaii
Honolulu, HI

Modifications:

Mike Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Purpose:

compress geosat data into 18 bytes/frame

| item | parameter | units | range | type |
|------|-----------------------|---------|-------------|-------------------|
| 1 | TIME since start a000 | ms | 0 to 1.47e9 | long int (4) |
| 2 | HEIGHT | cm | 0 to 32766 | short int (2) |
| 3 | CYCLE number | | 0... | char (1) |
| 4 | LATITUDE | 10-4deg | 0 to 18e5 | unsigned int (3) |
| 5 | LONGITUDE | 10-4deg | 0 to 36e5 | unsigned int (3) |
| 6 | SIGMA HEIGHT | cm | 0 to 255 | unsigned char (1) |
| 7 | SWH | 5cm | 0 to 255 | unsigned char (1) |
| 8 | So | .1db | 0 to 255 | unsigned char (1) |
| 9 | FLAGS | | | char (1) |
| 10 | OCEAN TIDE | cm | -128 to 128 | char (1) |

Method:

Reads in GDR, converts to 18 byte GDR and writes to
standard output

Usage:

g_compress < file.gdr > file.18b

Input:

GEOSAT GDR

Output:

18-byte data record

Subroutines required:

References:

```
*/
# include <stdio.h>

# define PERIOD 6037.551518571
# define START_TIME 58406188.43 /* equator xing orbit c000.a000 */
# define BAD 32767

/* this is the standard geosat frame */

struct in_frame {
    long int utc,utcm,lat,lon,orb;
    short int m_h,s_h,geoid,h[10],swh,s_swh,s_nght,agc,s_agc;
    char fl[2];
    short int h_off,s_tide,o_tide,w_fnoc,w_smmr,d_fnoc,iono,
              dh_swh,dh_fm,att;
};

struct in_frame in;

/* this is the compressed frame. Order is important since compiler
forces short int on even word boundaries */

struct out_frame {
    long int utc;
    short int m_h;
    char cycle_n;
    char lat[3],lon[3];
    unsigned char s_h,swh,s_nght;
    char fl;
    char o_tide;
};

struct out_frame out;

double time,cycle=244*PERIOD;

int i,j;

struct flags *f;

main()
{
    while(fread((char*)&in,1,78,stdin)==78)
    {
```

```

out.cycle_n=0;
time = in.utcm - START_TIME;

while(time >cycle)
{
    out.cycle_n++;
    time -= cycle;
}

out.utcm = nint(time*1000. + in.utcm/1000.);

in.lat = nint(in.lat/100.);
in.lat += 900000;
out.lat[0]=*((char*)&in.lat+1);
out.lat[1]=*((char*)&in.lat+2);
out.lat[2]=*((char*)&in.lat+3);

in.lon = nint(in.lon/100.);
out.lon[0]=*((char*)&in.lon+1);
out.lon[1]=*((char*)&in.lon+2);
out.lon[2]=*((char*)&in.lon+3);

out.m_h=in.m_h;

out.s_h=(in.s_h>255?255:(unsigned char)in.s_h);

in.swh = nint(in.swh/5.);
out.swh=(in.swh>255?255:(unsigned char)in.swh);

in.s_nght = nint(in.s_nght/10.);
out.s_nght=(in.s_nght>255?255:(unsigned char)in.s_nght);

out.fl=in.fl[1];

in.o_tide = nint(in.o_tide/10.);
out.o_tide=(abs(in.o_tide)>127?127:(char)in.o_tide);
fwrite((char*)&out,1,18,stdout);
}
}

```

Program g_correct.c

/*

@(#)g_correct.c 1.2 6/13/90

Program g_correct.c

Written by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Added comments and cleaned up some code.

Purpose:

This program will apply corrections to a GEOSAT
GDR as specified in the GEOSAT users manual. The following
correction will be applied:

h = h - solid tide
- ocean tide
- wet tropospheric correction (fnoc)
- dry tropospheric correction (fnoc)
- ionosphere correction
- inverse barometer effect

Where

inverse barometer effect = $-9.948 * (p - 1013.3)$

And

$p = \text{dry (fnoc)} / (-2.277)(1 + (0.0026 * \cos(2 * \text{latitude})))$

Method:

Reads raw GEOSAT GDRs from standard input and applies
corrections. Does not check for validity of input. Output
is in GDR format.

Usage:

The GEOSAT GDR is read from standard input.

cat c000.a002 | g_correct > c000.a002c

will apply corrections to all records from the GDR in c000.a002.

Input:

Stdin Raw GEOSAT GDRs

Output:

Stdout: Corrects GEOSAT GDRs

Subroutines Required:

bar.c Included, Calculates the inverse barometer effect.

References:

*/
include <math.h>
include <stdio.h>
include <string.h>
include "../include/geos.h"
include "../include/g_ext.h"

#define NUMARGS 6

int i,j,iarg;
main (argc,argv)
 int argc;
 char *argv[];
{

 float bar();
 float corr;

 if ((argc < 1) && (argc > NUMARGS+1))
 {
 fprintf(stderr,"Usage: %s [cet cot cwf cdf ci cib] < filein > fileout\n",
 argv[0]);
 exit(1);
 }

 while (fread((char*)&fr,1,REC_LEN,stdin)==REC_LEN)
 {
 /*
 Apply corrections here.
 */
 if(argc == 1) /* default apply all corrections */
 {
 fr.m_h = fr.m_h - nint((fr.s_tide + fr.o_tide + fr.w_fnoc
 + fr.d_fnoc + fr.iono
 + bar(fr.d_fnoc, fr.lat))/10.0);
 }
 else
 {
 corr = 0.0;


```

    for (iarg=1; iarg<argc; iarg++)
    {
        if(!strcmp(argv[iarg],val[25]))
        {
            corr += fr.s_tide;
        }
        else if (!strcmp(argv[iarg],val[26]))
        {
            corr += fr.o_tide;
        }
        else if (!strcmp(argv[iarg],val[27]))
        {
            corr += fr.w_fnoc;
        }
        else if (!strcmp(argv[iarg],val[29]))
        {
            corr += fr.d_fnoc;
        }
        else if (!strcmp(argv[iarg],val[30]))
        {
            corr += fr.iono;
        }
        else if (!strcmp(argv[iarg],val[34]))
        {
            corr += bar(fr.d_fnoc, fr.lat);
        }
        else
        {
            fprintf(stderr,"%s: illegal option %s ignored.\n",argv[0],
                    argv[iarg]);
        }
    }
}

fr.m_h = fr.m_h - nint(corr/10.0);

/*
Write out good data records.
*/

if (fwrite((char *)&fr, 1, REC_LEN, stdout) != REC_LEN)
{
    geo_error(3,argv[0]);
    exit(3);
}
}

float bar(d_fnoc, lat)
short d_fnoc;
long lat;

```

```

{
    float p;

    p = (d_inoc / ((-2.277)*(1 + (0.0026 * cos(2*M_PI*lat*1.e-6/180.)))));

    p = -9.948 * (p - 1013.3);

    return(p);
}

```

Program g_crossnum.c

```
/*
@(#)g_crossnum.c      1.3 6/14/90

Program g_crossnum.c

Written by:
-----
Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Purpose:
-----
To print out the longitude of the equator crossing of
a given orbit.

Method:
-----
Reads the orbit number from the command line or reads a
GDR from standard input. Calculates the equator crossing
and prints the result.

Usage:
-----
g_crossnum a002

or

g_crossnum < file.gdr

Input:
-----
Stdin      GDR file

Output:
-----
Stdout     Longitude of orbit crossing

Assumptions:
-----
Longitude is given as E positive from 0 to 360 degrees.

Subroutines Required:
-----
geo_cyc_orb.c      Determines cyc and orb from GDR
orb_cross.c        Determines where a particular orbit crosses
                    the equator.

References:
```

*/

```
#include <stdio.h>
#include <math.h>
#include <string.h>
#include "geos.h"
```

```
#define C_DEG 360.0/244.0 /* Degrees between successive geosat crossings */
```

```
main(argc,argv)
int argc;
char *argv[];
{
```

```
    float orb_cross();          /* Determines long. of equator crossing */
```

```
    char str[10];               /* Strings to parse input */
    char *s;
```

```
    int i, j;                   /* Counters */
    int orb_num;                 /* Orbit number */
    int asc;                     /* True if asc orbit */
    int cyc;                     /* Cycle number */
```

```
    struct frame fr2;           /* GEOSAT GDR */
```

```
    float crossing;             /* Equator crossing in degrees */
```

```
/*
    Read command line arguments...
*/
```

```
if (argc > 2)
{
    fprintf(stderr,"Usage: %s orbit\n",argv[0]);
    fprintf(stderr,"Or\n");
    fprintf(stderr,"%s < file.geo\n", argv[0]);
    exit(1);
}
```

```
if (argc == 2) /* Read orbit number from command line. */
{
    strncpy(str,argv[1]+1,3);
    sscanf(str,"%d",&orb_num);
    s = argv[1];
    switch(*s)
    {
        case 'a':
            asc = TRUE;
            break;
```

```

        case 'd':
            asc = FALSE;
            break;
        default:
            fprintf("%s: Illegal argument: %s\n", argv[0], argv[1]);
            exit(1);
    }

}

else /* Read GDR from standard input */
{
    if(fread((char *)&fr, 1, REC_LEN, stdin) != REC_LEN)
    {
        geo_error(3, argv[0]);
        exit(1);
    }
    if(fread((char *)&fr2, 1, REC_LEN, stdin) != REC_LEN)
    {
        geo_error(3, argv[0]);
        exit(1);
    }
    if ((fr2.lat - fr.lat) > 0) /* Ascending orbit */
    {
        asc = TRUE;
    }
    else
    {
        asc = FALSE;
    }
    geo_cyc_orb(fr, &cyc, &orb_num); /* Get orbit number */
}

crossing = orb_cross(orb_num, asc); /* Get crossing */

fprintf(stdout, "%f\n", crossing);

}

float orb_cross(orb_num, asc)
    int orb_num, asc;
{
    float lon;

    if (asc)
    {
        lon = 356.59 - orb_num*360.0*17./244.;
    }
    else
    {
        lon = 189.14 - orb_num*360.0*17./244.;
    }
    while (lon < 0.)
    {

```

```
        lon += 360.;  
    }  
    return (lon);  
}
```

Program g_date.c

/*

@(#)g_date.c 1.3 6/14/90

Written by:

Kenneth Borowski
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Modifications

Mike Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Added Comments and restructured code to use more consistent
naming convention.

Purpose:

Decode geosat data and convert Universal Time Coordinates to
month, day, year, Julian day, and day of cycle for the first
and last record in a file

Method:

Usage:

cat c000.a002 | g_date Gives start and end date of c000.a002

cat c000.* | g_date Gives start and end date of all orbits
 in cycle c000

Input:

Geosat GDR

Output:

Start and end time of GDR

Subroutines Required:

output Outputs start and end times
julday Calculates julian day
kdate Converts to month day and year

*/

```

# include <stdio.h>
# include <math.h>
# include "geos.h"

long int utcs, utcm;

main()

{
    fread((char*)&fr,1,REC_LEN,stdin);
    output(fr.utc,fr.utcm);
    while(fread((char*)&fr,1,REC_LEN,stdin) == REC_LEN) {
        utcs = fr.utc;
        utcm = fr.utcm;
    }
    output(utcs,utcm);
}

output(utcs,utcm)
long int utcs, utcm;
{
    int days,y,m,d;
    int seconds,minutes,hours;
    int orbit_num_tot;
    int cycle_num;
    int orbit_num;
    int day_of_year;

    double time;

    days = utcs / 86400;
    seconds = utcs % 86400;
    hours = seconds / 3600;
    minutes = (seconds % 3600) / 60;
    seconds = (seconds % 3600) % 60;
    kdate(days,&y,&m,&d);
    time = utcs + utcm / 1.0e6;
    orbit_num_tot = (int)floor((time-TIME_ZERO)/PERIOD);
    orbit_num = orbit_num_tot % 244;
    cycle_num = orbit_num * 17 / 244;
    day_of_year = julday(y,m,d) - julday(y-1,12,31);
    printf("\n      UTC: %11.2f\n", time);
    printf("      Date: %d/%d/%d %d:%.2d:%.2d\n", m,d,y,hours,minutes,seconds);
    printf("      Day of year: %d\n", day_of_year);
    printf("      Julian: %d\n", julday(y,m,d));
    printf("      Day of cycle: %d\n\n",cycle_num);
}

/* URI Julian day algorithm */
julday(y,m,d)
int y,m,d;{
return(367*y - 7*(y + (m+9)/12)/4 - 3*((y + (m-9)/7)/100 + 1)/4
      + 275*m/9 + d + 1721029);

```



```

    }
kdate(k,y,m,d)
/* converts the day, k, to month, day and year */
/* assumes that k = 1 corresponds to Jan 1, 1985 */
int k,*y,*m,*d;
{
    k = k + 30987;
    *y = (4 * k - 1) / 1461;
    *d = 4 * k - 1 - 1461 * (*y);
    *d = (*d + 4) / 4;
    *m = (5 * (*d) - 3) / 153;
    *d = 5 * (*d) - 3 - 153 * (*m);
    *d = (*d + 5) / 5;
    if (*m < 10)
        *m = *m + 3;
    else {
        *m = *m - 9;
        *y = *y + 1;
    }
}
}

```

Program g_date2.c

/*

g(#)g_date2.c 1.3 6/14/90

Written by:

Kenneth Borowski

Woods Hole Oceanographic Institution

Woods Hole, MA 02543

Modified by:

Mike Caruso

Woods Hole Oceanographic Institution

Woods Hole, MA 02543

Originally began as g_date.c and converted so that the input is
a cycle number and an orbit number.

Purpose:

Read a cycle and orbit number and determine the Universal Time
Coordinates of the beginning and end of that orbit and convert to
month, day, year, Julian day, and day of cycle for the first
and last record in a file.

Usage:

g_date2 000 192

Input:

cycle number

orbit number

Output:

Start and end time of GDR in various formats

Subroutines Required:

output Outputs start and end times

julday Calculates Julian Day

kdate Converts to month, day and year

geo_rcyc_orb Returns time for a given cycle and orbit

*/

#include <stdio.h>

#include <math.h>

```

#include "geos.h"

#define NUMARGS 2      /* Number of command line args */
#define CYARG 1        /* Number of cycle arg. */
#define ORARG 2        /* Number of orbit arg. */

long int utcs, utcm;    /* Universal time variables secs, microsecs */

main(argc, argv)
    int argc;
    char *argv[];
{
    double time;
    int cycle, orbit;

    if (argc != NUMARGS+1)
    {
        fprintf(stderr, "Usage: %s cycle orbit\n", argv[0]);
        exit(1);
    }

    sscanf(argv[CYARG], "%d", &cycle);
    sscanf(argv[ORARG], "%d", &orbit);

    geo_rcyc_orb(&time, cycle, orbit);
    output((int)time, 0);
    geo_rcyc_orb(&time, cycle, orbit+1);
    output((int)time, 0);
}

output(utcs, utcm)
long int utcs, utcm;
{
    int days, y, m, d;
    int seconds, minutes, hours;
    int orbit_num_tot;
    int cycle_num;
    int orbit_num;
    int day_of_year;

    double time;

    days = utcs / 86400;
    seconds = utcs % 86400;
    hours = seconds / 3600;
    minutes = (seconds % 3600) / 60;
    seconds = (seconds % 3600) % 60;
    kdate(days, &y, &m, &d);
    time = utcs + utcm / 1.0e6;
    orbit_num_tot = (int)floor((time-TIME_ZERO)/PERIOD);
    orbit_num = orbit_num_tot % 244;
    cycle_num = orbit_num * 17 / 244;

```

```

    day_of_year = julday(y,m,d) - julday(y-1,12,31);
    printf("\n      UTC: %11.2f\n", time);
    printf("      Date: %d/%d/%d %d:%.2d:%.2d\n", m,d,y,hours,minutes,seconds);
    printf("      Day of year: %d\n", day_of_year);
    printf("      Julian: %d\n", julday(y,m,d));
    printf("      Day of cycle: %d\n",cycle_num);
}
/* URI Julian day algorithm */
julday(y,m,d)
int y,m,d;{
return(367*y -7*(y + (m+9)/12)/4 - 3*((y + (m-9)/7)/100 +1)/4
      + 275*m/9 + d + 1721029);
}
kdate(k,y,m,d)
/* converts the day, k, to month, day and year */
/* assumes that k = 1 corresponds to Jan 1, 1985 */
int k,*y,*m,*d;
{
    k = k + 30987;
    *y = (4 * k - 1) / 1461;
    *d = 4 * k - 1 - 1461 * (*y);
    *d = (*d + 4) / 4;
    *m = (5 * (*d) - 3) / 153;
    *d = 5 * (*d) - 3 - 153 * (*m);
    *d = (*d + 5) / 5;
    if (*m < 10)
        *m = *m + 3;
    else {
        *m = *m - 9;
        *y = *y + 1;
    }
}

/*
Subroutine geo_rcyc_orb.c
*/

int geo_rcyc_orb(time, cyc, orb)
double *time;
int cyc;
int orb;
{
    int orbit;

    orbit = cyc * ORB_PER_CYC + orb;

    *time = orbit*PERIOD + TIME_ZERO;
}

```

Program g_ext.c

/*

@(#)g_ext.c 1.4 4/25/90

Program g_ext.c

Written by:

Pierre Flament

University of Hawaii

Honolulu, HI 96822

Modifications:

Michael Caruso

Woods Hole Oceanographic Institution

Woods Hole, MA

Added comments and cleaned up some code.

Purpose:

To extract user specified data from a GEOSAT GDR.

Method:

Reads raw GEOSAT GDRs from standard input and applies corrections. Reads user desired output variables from command line arguments. Write output on standard output. Output is in ASCII format.

Usage:

The GEOSAT GDR is read from standard input and output variables are read from command line.

cat c000.a002 | g_ext t l L > file.asc

will extract the time, the latitude and the longitude for each good point in the file c000.a002.

cat c000.a002 | gext l L ha > file.asc

will extract the latitude, the longitude and the sea surface height above the ellipsoid.

Input:

Stdin

Raw GEOSAT GDRs

Output:

Stdout: Extracted data in ASCII format

Subroutines Required:

References:

```
*/
# include <math.h>
# include <stdio.h>
# include <string.h>
# include "geos.h"
# include "g_ext.h"

# define MXP        26                    /* max number of parameters */

# define PRINT(X) printf(form[col[i]],X)

int i,j;
int col[MXP];
int bad;
short int msk,valid;

char * getenv();
double h(),bar();

/* geosat data frame. Use this instead of fr to get two arrays, one
   long int and one short int. Need to be careful with the indices. */

struct {
    long int x[5];
    short int y[NCHAN-5];
} v;

main (argc,argv)
    int argc;
    char *argv[];

{
    for(j=0;j<MXP;j++)
        col[j] = -1;

    argc--;
    argv++;

    if (argc==0)
    {
        fprintf(stderr,"gext: argument error\n");
        exit(1);
    }
}
```

```

/* find which channels should be processed
i: argument/column index
j: channel number
col[i]: channel number corresponding to column i
*/

for (i=0;i<argc;i++)
  for (j=0;j<NCHAN+3;j++)
    if(!strcmp(argv[i],val[j]))
    {
      col[i]=j;
      break;
    }

/* get from the environment which bits of the flags should be masked
and which values constitute a valid frame */

geo_mask(&msh,&valid);

while (fread((char*)&v,1,78,stdin)==78)
{
  if (bad) continue;      /* If bad skip print and get next point. */

  for (i=0;i<argc;i++)    /* Print requested data */
    if (col[i]==0)
      PRINT(v.x[0]*conv[0]+v.x[1]*conv[1]-START_TIME);
    else if (col[i]<5)
      PRINT(v.x[col[i]]*conv[col[i]]);
    else if (col[i]==5)
      PRINT(v.y[0]*conv[5]+v.y[19]*conv[24]);
    else if (col[i]<NCHAN)
      PRINT(v.y[col[i]-5]*conv[col[i]]);
    else if (col[i]==NCHAN)
      PRINT(bar());
    else if (col[i]==NCHAN+1)
      PRINT(h());
    else if (col[i]==NCHAN+2)
      PRINT(h()-v.y[2]*conv[7]);
    printf("\n");
  }
}

double h()
/* compute corrected height based on suggested
corrections in the GEOSAT altimeter GDR user handbook
*/
{
double x;

x=v.y[0]*conv[5]+v.y[19]*conv[24]
-v.y[20]*conv[25]

```

```

        -v.y[21]*conv[26]
        -v.y[22]*conv[27]
        -v.y[24]*conv[29]
        -v.y[25]*conv[30];
return(x-bar());
}

double bar()
/* inverse barometric effect in m using the formula
   provided in the GEOSAT altimeter GDR user handbook
   */
{
double p;

p= v.y[24]/(-2.277*(1+0.0026*cos(2*M_PI*v.x[2]*conv[2]/180.)));
return(-9.948*(p-1013.3)*1.e-3);
}

```


Program g_image.c

/*

@(#)g_image.c 1.4 6/14/90

Written by:

Pierre Flament
University of Hawaii
Honolulu, HI 96822

Modified by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Changed to allow different output sizes and to
output sdps floating point format.

Purpose:

To generate bitmap images of GEOSAT data.

Method:

Reads ascii files of lat, lon, z and converts to
a bitmap image in sdps floating point format.

Usage:

g_image 20 40 190 210 512 512 < file.asc > file.sdpsf

Input:

Stdin All lat, lon and z values.

Output:

Stdout Image in SDPS floating point format

Assumptions:

Longitude is E positive from 0 to 360 degrees.

Subroutines Required:

write_sdps Writes out an SDPS format file.

References:

 Satellite Data Processing System (SDPS) Users Manual V1.0,
 Michael Caruso and Chris Dunn, Woods Hole Oceanog. Inst. Tech. Rept.,
 WHOI-89-13

```

*/

#include <stdio.h>
#include <math.h>
#include "sdpsutil.h"

/*
  Define argument places here.
*/
#define NUMARGS 6
#define MNLAT 1
#define MXLAT 2
#define MNLOW 3
#define MXLOW 4
#define ROW 5
#define COL 6

#define S_DEG 20      /* number of GEOSAT samples per degree*/

main(argc,argv)
int argc;
char *argv[];
{

  double min_lat, min_lon, max_lat, max_lon;
  double lat, lon, z;
  int i, j, dlat, dlon, ilat, ilon;
  int row, col, rowoff, ij;

  struct sdpsheader    header;
  struct sdpscmap      cmap;
  float                *im;

  /*
    Read command line arguments...
  */

  if (argc != NUMARGS+1)
  {
    fprintf(stderr,
      "Usage: g_image min_lat, max_lat, min_lon, max_lon row col\n");
    exit(1);
  }

  sscanf(argv[MNLAT], "%lf", &min_lat);
  sscanf(argv[MXLAT], "%lf", &max_lat);
  sscanf(argv[MNLOW], "%lf", &min_lon);
  sscanf(argv[MXLOW], "%lf", &max_lon);
  sscanf(argv[ROW], "%d", &row);

```

```

    sscanf(argv[COL], "%d", &col);
/*
    Allocate storage for im...
*/

    im = (float *)malloc(sizeof(float) * row * col);

    while (!feof(stdin))
    {
        fscanf(stdin, "%lf %lf %lf", &lat, &lon, &z);

/* simple registration algorithm, image starts at top left corner */

        ilon=(lon-min_lon)/(max_lon-min_lon)*(col-1);
        if (ilon<0 || ilon > col-1) continue;
        ilat=row-1-(lat-min_lat)/(max_lat-min_lat)*(row-1);
        if (ilat<0 || ilat > row-1) continue;

/* get lon and lat rectangle size */

        dlon=col*(360./244.)/(max_lon-min_lon)/2.+1;
        dlat=row/(max_lat-min_lat)/S_DEG+2;

        for(j=(ilat<0?0:ilat);j<ilat+dlat && j<row;j++)
        {
            rowoff = j * col;
            for(i=(ilon-dlon<0?0:ilon-dlon);i<=ilon+dlon && i<col;i++)
            {
                ij = rowoff + i;
                im[ij] = (float)z;
            }
        }
    }

/*
    Create sdps format file..

    header.annot = "Geosat Image";
*/
    strcpy(header.annot, "Geosat Image");

    header.type    = FLOAT;
    header.dim     = 2;
    header.ind[0]  = col;
    header.ind[1]  = row;
    header.ind[2]  = 1;
    header.ind[3]  = 1;
    header.inc[0]  = dlon;
    header.inc[1]  = dlat;
    header.inc[2]  = 1;
    header.inc[3]  = 1;

```

```
header.slope = 1.0;
header.intrcp = 0.0;
header.cmap = 0;

write_sdps(stdout, header, cmap, in);
}
```

Program g_interp.c

/*

@(#)g_interp.c 1.3 12/15/89

Program g_interp.c

Written by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Modifications:

12-15-89 MC Changed call to geo_cyc_orb so that time is
 passed and not a GDR.

Purpose:

This program will linearly interpolate all geosat GDR data except the
10 per second heights and the flags against the latitude value.

Method:

1. Break data into continuous segments
2. Interpolate each data value to a common grid.
3. Write out all data between min and max.

Usage:

The GEOSAT GDR is read from standard input.

cat c000.a002 | g_interp dir min max deltax timestep> c000.a002s

will spline the records from the GDR in c000.a002 between min
and max latitude if dir is 1 and between min and max longitudes
if dir is 2.

Input:

| | |
|---------|---|
| Stdin | Clean GEOSAT GDRs |
| dir | Determines boundaries of spline: |
| | 1 - Use latitude |
| | 2 - Use longitude |
| min | Minimum lat or lon. |
| max | Maximum lat or lon. |
| deltmax | Maximum gap in seconds for a contiguous segment. |

timestep Interval between interpolated points.

Output:

Stdout: Interpolated GEOSAT GDRs. Values in gaps
 between valid segments are set to all
 zeros.

Subroutines and Subprograms Required:

geo_cyc_orb Returns the cycle number and orbit number
 for a given time.
fit_time Initializes interpolation variables and fits an
 interpolation to the time variable.
fit_data Interpolates between points of a given data
 set.

References:

*/
include <math.h>
include <stdio.h>
include "geos.h"

#define NUMARGS 5
#define DIARG 1
#define MIARG 2
#define MAARG 3
#define DEARG 4
#define TIARG 5
#define MICRO 1e-6 /* Conv for utcm */
#define MAXPOINTS 2915 /* +/- .degrees latitude */

/*
 Define some globals to share with fit subprograms...
*/

int ii, j, k;
int latstart, latstop;
struct frame frsin[MAXPOINTS]; /* frame MAXPOINTS/2 is defined at the equator */
struct frame frout[MAXPOINTS];
float timestep;
short int points=0;
float *x;
float *y2;
float *lat;
float *y;

float x0, minval, maxval;

/*
 Variables for orbit analysis.
*/

```

int cyc, orb;
double rs, rs3, cosinc, prec, rot, dthdt;
double time, theta, sinth, lat0, lon0, tmp;

short int seg_len[1000];
short int seg_beg[1000];

unsigned char ascorb;

main (argc,argv)
    int argc;
    char *argv[];
{
    /*
    Declare subroutines and subprograms...
    */

    int fit_time();
    int fit_data();
    int geo_cyc_orb();

    double          time1, time2;  /* time variable used to determine gap */

    float deltmx;

    short int i;

    short int dir;
    short int segments = 0;

    static char SccsId[] = "0(#)g_spline.c      1.4\t6/23/89";

    x = (float *)calloc(MAXPOINTS, sizeof(float));
    y2 = (float *)calloc(MAXPOINTS, sizeof(float));
    y = (float *)calloc(MAXPOINTS, sizeof(float));
    lat = (float *)calloc(MAXPOINTS, sizeof(float));

    if ((argc != NUMARGS+1) && (argc != 1))
    {
        fprintf(stderr,
            "Usage: %s [dir min max deltmx timestep] < filein > filout\n",
            argv[0]);
        exit(1);
    }
    if (argc == NUMARGS+1)
    {
        sscanf(argv[DIARG], "%hd", &dir);
        sscanf(argv[MIARG], "%f", &minval);
        sscanf(argv[MAARG], "%f", &maxval);
        sscanf(argv[DEARG], "%f", &deltmx);
    }

```

```

        sscanf(argv[TIARG], "%i", &timestep);
    }
else
    {
        fprintf(stderr,
            "Usage: %s [dir min max deltax timestep] < filein > filout\n",
            argv[0]);
        exit(1);
    }

/*
    Read in all GDRs...
*/
while (fread((char*)&frsin[points], 1, REC_LEN, stdin) == REC_LEN) points++;
points--;

if (points <= 0)
{
    fprintf(stderr, "%s: No points to spline\n\n", argv[0]);
    exit(0);
}

/*
    Determine if orbit is ascending or descending...
*/
if((frsin[0].lat < frsin[1].lat) && (frsin[1].lat < frsin[points].lat))
{
    ascorb = TRUE;
}
else if((frsin[0].lat > frsin[1].lat) && (frsin[1].lat > frsin[points].lat))
{
    ascorb = FALSE;
}
else
{
    fprintf(stderr, "%s: Unable to determine if orbit is ascending or ");
    fprintf(stderr, "descending\n", argv[0]);
    exit(1);
}

/*
    Set up for direction.  If dir != 1, then we
    find the latitude that corresponds to minlon
    and maxlon.
*/
if (dir != 1)
{
    lon_to_lat();
}

/*
    Fill latitude array and find starting index...
*/
for (i=0; i< MAXPOINTS; i++)

```



```

{
    if (ascorb)
    {
        lat[i] = DEG*asin(sin((i-MAXPOINTS/2)*timestep*M2PI/PERIOD)*sin(INC));
        if (minval > lat[i]) latstart = i+1;
    }
    else
    {
        lat[i] = DEG*asin(sin(((MAXPOINTS/2)-i)*timestep*M2PI/PERIOD)*sin(INC));
        if (maxval < lat[i]) latstart = i+1;
    }
}

}

/*
1. Break into data segments...
*/
seg_len[0] = 1;
seg_beg[0] = 0;
time2 = frsin[0].utc + frsin[0].utcm*MICRO;
for (i=0; i<points; i++)
{
    time1 = time2;
    time2 = frsin[i+1].utc + frsin[i+1].utcm*MICRO;

    if ((time2 - time1) <= deltax)
    {
        seg_len[segments]++;
    }
    else
    {
        segments++;
        seg_beg[segments] = i + 1;
        seg_len[segments] = 1;
    }
}

if (seg_len[0] == 0) exit(1);

/*
2. Initialize data and fit a spline to each segment...
*/
for(i=latstart; i<MAXPOINTS; i++)
{
    frout[i].lat = (int)(lat[i]/MICRO);
    frout[i].lon = BAD;
    frout[i].m_h = BAD;
}

for (i=0; i<=segments; i++)
{
    fit_time(i);          /* initialize spline */
}

```

```

        fit_data(i,0);          /* lon */
        fit_data(i,1);          /* h */
        fit_data(i,2);          /* orb */
        fit_data(i,3);          /* s_h */
        fit_data(i,4);          /* geoid */
        fit_data(i,5);          /* swh */
        fit_data(i,6);          /* s_swh */
        fit_data(i,7);          /* s_nght */
        fit_data(i,8);          /* agc */
        fit_data(i,9);          /* s_agc */
        fit_data(i,10);         /* s_tide */
        fit_data(i,11);         /* o_tide */
        fit_data(i,12);         /* w_fnoc */
        fit_data(i,13);         /* w_smmr */
        fit_data(i,14);         /* d_fnoc */
        fit_data(i,15);         /* iono */
        fit_data(i,16);         /* dh_swh */
        fit_data(i,17);         /* dh_fm */
        fit_data(i,18);         /* att */
    }

/*
Write out points...
*/

    for (k=latstart; k<j; k++)
    {
        if (fwrite((char *)&frount[k], 1, REC_LEN, stdout) != REC_LEN)
        {
            geo_error(3,argv[0]);
            exit(3);
        }
    }

}

/*
-----
Subroutine fit_time
Written by:
    Michael Caruso
    Woods Hole Oceanographic Institution
    Woods Hole, MA

Purpose:
    This subprogram fits a spline to the time variable in a
    GEOSAT GDR.
-----
*/

int fit_time(i)
    int i;
{

```

```

double yout;
ii = 0;
for (j=seg_beg[i]; j<seg_beg[i]+seg_len[i]; j++)
{
    x[ii] = frsin[j].lat*MICRO;
    y[ii] = (float)(frsin[j].utc - frsin[seg_beg[i]].utc)
        + (float)frsin[j].utcm*MICRO;
    ii++;
}
x0 = x[0];

j = latstart;
while ((ascorb && (lat[j] < x0)) || (!ascorb && (lat[j] > x0)))
{
    j++;
}
while ((lat[j] > minvr1) && (lat[j] < maxval))
{
    if ((ascorb && (lat[j] > frsin[seg_beg[i]].lat*MICRO) &&
        (lat[j] < frsin[seg_beg[i]+seg_len[i]-1].lat*MICRO)) ||
        (!ascorb && (lat[j] < frsin[seg_beg[i]].lat*MICRO) &&
        (lat[j] > frsin[seg_beg[i]+seg_len[i]-1].lat*MICRO)))
    {
        ii = 0;
        if (ascorb)
        {
            while(x[ii] < lat[j])
                ii++;
        }
        else
        {
            while(x[ii] > lat[j])
                ii++;
        }

        linear((double)x[ii], (double)y[ii], (double)x[ii-1],
            (double)y[ii-1], (double)lat[j], &yout);

        frout[j].utc = (int)yout + frsin[seg_beg[i]].utc;
        frout[j].utcm = (int)((yout - (int)yout)/MICRO);
    }
    else
    {
        frout[j].lat = (int)(lat[j]/MICRO);
        frout[j].utc = 0;
        frout[j].utcm = 0;
    }
    j++;
}

return;

```

```

}
/*
-----
Subroutine fit_data
Written by:
Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Purpose:
This subprogram fits a spline to the data segment
specified.
-----
*/

int fit_data(i, var)
    int i, var;
{
    double yout;
    int iout;
    ii = 0;
    for (j=seg_beg[i]; j<seg_beg[i]+seg_len[i]; j++)
    {
        x[ii] = frsin[j].lat*MICRO;
        switch (var)
        {
            case 0:
                y[ii] = (float)frsin[j].lon;
                break;
            case 1:
                y[ii] = (float)frsin[j].m_h;
                break;
            case 2:
                y[ii] = (float)frsin[j].orb;
                break;
            case 3:
                y[ii] = (float)frsin[j].s_h;
                break;
            case 4:
                y[ii] = (float)frsin[j].geoid;
                break;
            case 5:
                y[ii] = (float)frsin[j].swh;
                break;
            case 6:
                y[ii] = (float)frsin[j].s_swh;
                break;
            case 7:
                y[ii] = (float)frsin[j].s_nght;
                break;
            case 8:
                y[ii] = (float)frsin[j].agc;

```

```

        break;
    case 9:
        y[i1] = (float)frsin[j].s_agc;
        break;
    case 10:
        y[i1] = (float)frsin[j].s_tide;
        break;
    case 11:
        y[i1] = (float)frsin[j].o_tide;
        break;
    case 12:
        y[i1] = (float)frsin[j].w_fnoc;
        break;
    case 13:
        y[i1] = (float)frsin[j].w_smar;
        break;
    case 14:
        y[i1] = (float)frsin[j].d_fnoc;
        break;
    case 15:
        y[i1] = (float)frsin[j].iono;
        break;
    case 16:
        y[i1] = (float)frsin[j].dh_swh;
        break;
    case 17:
        y[i1] = (float)frsin[j].dh_fm;
        break;
    case 18:
        y[i1] = (float)frsin[j].att;
        break;
    default:
        return(1);
    }

    ii++;
}
x0 = x[0];

j = latstart;
while ((ascorb && (lat[j] < x0)) || (!ascorb && (lat[j] > x0)))
{
    j++;
}
while ((lat[j] > minval) && (lat[j] < maxval))
{
    if ((ascorb && (lat[j] > frsin[seg_beg[i]].lat*MICRO) &&
        (lat[j] < frsin[seg_beg[i]+seg_len[i]-1].lat*MICRO)) ||
        (!ascorb && (lat[j] < frsin[seg_beg[i]].lat*MICRO) &&
        (lat[j] > frsin[seg_beg[i]+seg_len[i]-1].lat*MICRO)))
    {
        ii = 0;
        if (ascorb)
        {

```

```

        while(x[ii] < lat[j])
            ii++;
    }
    else
    {
        while(x[ii] > lat[j])
            ii++;
    }

    linear((double)x[ii], (double)y[ii], (double)x[ii-1],
           (double)y[ii-1], (double)lat[j], &yout);

    iyout = nint(yout);
    set_data(j, iyout, var);
}
else
{
    set_data(j, BAD, var);
}
j++;
}
natsubspline(x, y, ii, lat[j], &yout, 2);

return(0);
}

```

/*

Subroutine set_data

Written by:

Michael Caruso

Woods Hole Oceanographic Institution

Woods Hole, MA

Purpose:

This subroutine simply puts the data into the
correct element.

*/

```

int set_data(point, data, var)
    int point;
    int data;
    int var;
{
    switch (var)
    {
        case 0:
            frout[point].lon = data;
            break;
        case 1:
            frout[point].m_h = data;
            break;
        case 2:

```

```

        front[point].orb = data;
        break;
    case 3:
        front[point].s_h = data;
        break;
    case 4:
        front[point].geoid = data;
        break;
    case 5:
        front[point].swh = data;
        break;
    case 6:
        front[point].s_swh = data;
        break;
    case 7:
        front[point].s_nght = data;
        break;
    case 8:
        front[point].agc = data;
        break;
    case 9:
        front[point].s_agc = data;
        break;
    case 10:
        front[point].s_tide = data;
        break;
    case 11:
        front[point].o_tide = data;
        break;
    case 12:
        front[point].w_fnoc = data;
        break;
    case 13:
        front[point].w_smmr = data;
        break;
    case 14:
        front[point].d_fnoc = data;
        break;
    case 15:
        front[point].iono = data;
        break;
    case 16:
        front[point].dh_swh = data;
        break;
    case 17:
        front[point].dh_fm = data;
        break;
    case 18:
        front[point].att = data;
        break;
    default:
        return(1);
    }
}

```

```

/*
-----
Subroutine lon_to_lat

Written by:
  Michael Caruso
  Woods Hole Oceanographic Institution
  Woods Hole, MA

Purpose:
  This subroutine converts the minval and
  maxval when given in longitude to latitude.
-----
*/
int
lon_to_lat()

{
  int i;
  float tmpval;
  double tmptime;

  /* Determine orbit number */

  tmptime = frsin[0].utc + frsin[0].utcm*MICRO;
  geo_cyc_orb(tmptime, &cyc, &orb);

  rs = RE + frsin[0].orb;
  rs3 = rs*rs*rs;
  cosinc = cos(INCL);
  prec = -1.5*J2*sqrt(GM/rs)*RE*RE*cosinc/rs3;
  rot = prec - (M_PI_2/SD);
  dthdt = M2PI/PERIOD;

  /*
    Loop until we find min_lat and
    max_lat.
  */

  lon0 = frsin[0].lon*1.0e-6*RAD;
  time = 0.0;

  if (ascorb)
  {
    i = 0;
    while (lon0 > maxval*RAD)
    {
      i++;
      lon0 = frsin[i].lon*1.0e-6*RAD;
    }
  }
}

```



```

while (lon0 < maxval*RAD)
{
    time -= timestep;
    theta = dthdt*time;
    sinth = sin(theta);
    lat0 = (frsin[i].lat*1.0e-6)*RAD + asin(sin(INCL)*sin(theta));
    tmp = cosinc*sinth/cos(lat0);
    tmp = (tmp>1.0) ? 1.0 : tmp;
    tmp = (tmp<-1.0) ? -1.0 : tmp;
    lon0 = (asin(tmp) + rot*time) + frsin[i].lon*1.0e-6*RAD;
}

lon0 = frsin[points].lon*1.0e-6*RAD;
tmpval = lat0*DEG;
time = 0.0;
i = points;
while (lon0 < minval*RAD)
{
    i--;
    lon0 = frsin[i].lon*1.0e-6*RAD;
}
while (lon0 > minval*RAD)
{
    time += timestep;
    theta = dthdt*time;
    sinth = sin(theta);
    lat0 = (frsin[i].lat*1.0e-6)*RAD + asin(sin(INCL)*sin(theta));
    tmp = cosinc*sinth/cos(lat0);
    tmp = (tmp>1.0) ? 1.0 : tmp;
    tmp = (tmp<-1.0) ? -1.0 : tmp;
    lon0 = (asin(tmp) + rot*time) + frsin[i].lon*1.0e-6*RAD;
}
minval = tmpval;
maxval = lat0*DEG;
}
else
{
    lon0 = frsin[0].lon*1.0e-6*RAD;
    time = 0.0;
    i = 0;
    while (lon0 > maxval*RAD)
    {
        i++;
        lon0 = frsin[i].lon*1.0e-6*RAD;
    }

    while (lon0 < maxval*RAD)
    {
        time -= timestep;
        theta = dthdt*time;
        sinth = sin(theta);
        lat0 = (frsin[i].lat*1.0e-6)*RAD + asin(sin(INCL)*sin(theta));
        tmp = cosinc*sinth/cos(lat0);

```

```

    tmp = (tmp>1.0) ? 1.0 : tmp;
    tmp = (tmp<-1.0) ? -1.0 : tmp;
    lon0 = (asin(tmp) + rot*time) + frsin[i].lon*1.0e-6*RAD;
}

maxval = lat0*DEG;
lon0 = frsin[points].lon*1.0e-6*RAD;
time = 0.0;
i = points;
while (lon0 < minval*RAD)
{
    i--;
    lon0 = frsin[i].lon*1.0e-6*RAD;
}
while (lon0 > minval*RAD)
{
    time += timestep;
    theta = dthdt*time;
    .sinh = sin(theta);
    lat0 = (frsin[i].lat*1.0e-6)*RAD + asin(sin(INCL)*sinh);

    tmp = cosinc*sinh/cos(lat0);
    tmp = (tmp>1.0) ? 1.0 : tmp;
    tmp = (tmp<-1.0) ? -1.0 : tmp;
    lon0 = (asin(tmp) + rot*time) + frsin[i].lon*1.0e-6*RAD;
}
minval = lat0*DEG;
}
}

```

Program g_print.c

```
/*
e(#)g_print.c 1.3 6/14/90

Written by:
-----
Pierre Flament
University of Hawaii
Honolulu, HI 96822

Modifications:
-----
Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Added Comments and cleaned up some of code.

Purpose:
-----
Decodes Geosat GDR record and prints in a
lengthy format.

Method:
-----
Reads Geosat GDR from standard input and converts
each element to ascii and prints each element with
an identifier to standard output.

Usage:
-----
g_print < c???.a???

Input:
-----
c???.a???      Raw Geosat GDRs from standard input.

Output:
-----
Standard Output      Formatted output.

Note:
-----
The flags are ordered as follows:

FEDCBA9876543210

where 0 is the zeroth flag bit
and F is the fifteenth flag bit as
listed in the Geosat Altimeter GDR User
```

Handbook.

Subroutines Required:

None.

```
*/
# include <stdio.h>
# include "geos.h"

/* Labels for output... */

char *xlab[]={ "utc ",
               "utcm",
               "lat ",
               "lon ",
               "orb "};

char *ylab[]={ "m_h      ",
               "s_h      ",
               "geoid    ",
               "h[1]     ",
               "h[2]     ",
               "h[3]     ",
               "h[4]     ",
               "h[5]     ",
               "h[6]     ",
               "h[7]     ",
               "h[8]     ",
               "h[9]     ",
               "h[10]    ",
               "swh      ",
               "s_swh    ",
               "s_naught ",
               "agc      ",
               "s_agc    "};

char *zlab[]={ "h_off   ",
               "sol_tide",
               "oc_tide ",
               "wet_fnoc",
               "wet_smar",
               "dry_fnoc",
               "iono_gps",
               "dh_swh  ",
               "dh_fm   ",
               "att     "};

short int    i,j;
long int     record = 0;
```

```

struct      flags *f;

main()

{

while(fread((char*)&fr,1,REC_LEN,stdin)==REC_LEN)
{
    printf("\f");

    printf("Record Number:\t%10ld\n",++record);
    printf("%s :\t%10ld\t",xlab[0],fr.utc);
    printf("%s :\t%10ld\n",xlab[1],fr.utcm);
    printf("%s :\t%10ld\t",xlab[2],fr.lat);
    printf("%s :\t%10ld\n",xlab[3],fr.lon);
    printf("%s :\t%10ld\n",xlab[4],fr.orb);

    printf("\n");

    printf("%s :\t%6d\t",ylab[0],fr.m_h);
    printf("%s :\t%6d\n",ylab[1],fr.s_h);
    printf("%s :\t%6d\n",ylab[2],fr.geoid);
    for(i=0; i<10; i++)
    {
        if(i%2)
            printf("%s :\t%6d\n",ylab[i+3],fr.h[i]);
        else
            printf("%s :\t%6d\t",ylab[i+3],fr.h[i]);
    }
    printf("%s :\t%6d\t",ylab[13],fr.swh);
    printf("%s :\t%6d\n",ylab[14],fr.s_swh);
    printf("%s :\t%6d\n",ylab[15],fr.s_nght);
    printf("%s :\t%6d\t",ylab[16],fr.agc);
    printf("%s :\t%6d\n",ylab[17],fr.s_agc);

    f = &(fr.fl);
    printf("\nflags (0-15 right to left):\t%d%d%d%d%d%d%d%d%d%d%d%d\n\n",
        f->junk15,f->junk14,f->s,f->t,f->junk11,f->junk10,f->junk09,
        f->junk08,f->junk07,f->a6,f->a5,f->a4,f->h,f->r,f->d,f->w);

    printf("%s :\t%6d\n",zlab[0],fr.h_off);
    printf("%s :\t%6d\t",zlab[1],fr.s_tide);
    printf("%s :\t%6d\n",zlab[2],fr.o_tide);
    printf("%s :\t%6d\t",zlab[3],fr.w_fnoc);
    printf("%s :\t%6d\t",zlab[4],fr.w_smmr);
    printf("%s :\t%6d\n",zlab[5],fr.d_fnoc);
    printf("%s :\t%6d\n",zlab[6],fr.iono);
    printf("%s :\t%6d\n",zlab[7],fr.dh_swh);
    printf("%s :\t%6d\n",zlab[8],fr.dh_fm);
    printf("%s :\t%6d\n",zlab[9],fr.att);

}

}

```

Program g_region.c

/*

@(#)g_region.c 1.5 12/19/89

Program g_region.c

Written by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Modifications:

12-15-89 MC Changed call to geo_cyc_orb so that time is
passed and not a GDR.

Purpose:

Decodes GEOSAT data and separates raw data into separate orbits. Each orbit is defined as beginning at the northernmost point of a track. Each orbit is further separated into an ascending section and a descending section. Orbits are then written out to separate files of the form:

cccc.aann or cccc.nnnd

where

| | |
|------|-------------------------------------|
| cccc | is the cycle number, |
| ann | is the orbit number for that cycle, |
| a | signifies ascending portion, |
| d | signifies descending portion. |

The data is written out in the same form as it was read in. This is consecutive records of 78 bytes each.

Usage:

The program reads the minimum and maximum latitudes and longitudes from the command line and reads the data from standard input. To use the program to extract data from tape (/dev/rmt8, 6250bpi, input block size 16380) HP format from NODC, from 10N to 30N and 280E to 300E:

dd if=/dev/rmt8 ibs=16380 files=34 | g_region 1 10 30 280 300

The first number on the argument line specifies whether the box should be bounded by a latitude line(1) or a longitude line(2). Note that longitudes are all east of Greenwich and if the box selected spans 360E, add 360 degrees to right edge of box, ie 350 365.

Input:

Stdin Raw Geosat GDRs

Output:

c???.???? Geosat data within region separated in ascending and
 descending orbits.

Subroutines and Subprograms Required:

geo_cyc_orb Returns the cycle number and orbit number
 for a given time.
geo_which returns an array of 1's and 0's for each cycle
 within the desired box.
geo_error prints error messages to standard error.

References:

Bugs:

 Assumes input data contains complete orbits.

*/

```
#include <stdio.h>
#include <sys/file.h>
#include <math.h>
#include "geos.h"
```

```
#define NUMARG 5
#define DIRARG 1
#define MNLTARG 2
#define MXLTARG 3
#define MNLWARG 4
#define MXLWARG 5
```

```
main(argc, argv)
    int argc;
    char *argv[];
{
```

```
    struct frame fr2;
```

```
    unsigned char a[ORB_PER_CYC],
                  d[ORB_PER_CYC],
                  c[ORB_PER_CYC]; /* arrays of orbits within box */
```

```
    char            str[80];            /* string for output file name */
```

```
    int            i,j;                /* Counters */
```

```

short int    dir;           /* Direction of lat/lon boundary      */
short int    orbit_num_tot; /* the total number of orbits      */
int          cycle_num;     /* the number of cycles since      */
int          orbit_num;     /* orbit number within cycle 0-244 */
short int    isopen = FALSE; /* check to see if file is already open */
short int    asc;           /* flag for ascending or descending */

long int     llcmp,
             llmin, llmax;   /* lat/lon boundary                */
long int     lslope1,
             lslope2;       /* "Slope" of orbit                */

double       min_lat,
             max_lat,
             min_lon,
             max_lon;       /* input lon-lat box              */
double       time;          /* time variable                   */

FILE *fdout;                /* output file descriptor          */

/*
Read command line arguments.
*/

if (argc >= NUMARG + 1)
{
    sscanf(argv[DIRARG], "%hd", &dir);
    sscanf(argv[MNLTARG], "%lf", &min_lat);
    sscanf(argv[MXLTARG], "%lf", &max_lat);
    sscanf(argv[MNLTARG], "%lf", &min_lon);
    sscanf(argv[MXLTARG], "%lf", &max_lon);
}
else
{
    fprintf(stderr,
        "Usage: %s dir min_lat max_lat min_lon max_lon [orb#]\n", argv[0]);
    exit(1);
}

/* determine orbits to remove. */

geo_which(min_lat, max_lat, min_lon, max_lon, a, d);

/*
Mask out orbit numbers if given on command line...
*/
if (argc > NUMARG+1)
{
    for (i=6; i<argc; i++)

```



```

        {
            sscanf(argv[i], "%d", &j);
            c[j] = TRUE;
        }
    for (i=0; i<ORB_PER_CYC; i++)
    {
        a[i] = a[i] && c[i];
        d[i] = d[i] && c[i];
    }
}

/* Set llmin, llmax... */

if (dir == 1)
{
    llmin = (int) (min_lat*1.0e06);
    llmax = (int) (max_lat*1.0e06);
}
else
{
    llmin = (int) (min_lon*1.0e06);
    llmax = (int) (max_lon*1.0e06);
}

/* read initial lat and long coordinates */

if(fread((char *)&fr,1,REC_LEN,stdin) != REC_LEN)
{
    geo_error(2, argv[0]);
    exit(2);
}

if(fread((char *)&fr2,1,REC_LEN,stdin) != REC_LEN)
{
    geo_error(2, argv[0]);
    exit(2);
}

/* Determine name of first orbit */

time = fr.utcm + fr.utcm * 1.0e-6;
lslope1 = fr2.lat - fr.lat;

geo_cyc_orb(time, &cycle_num, &orbit_num);

/*
Check to see if first orbit is ascending or
descending...
*/

if ( lslope1 > 0 )
{
    sprintf(str,"c%.3d.a%.3d",cycle_num,orbit_num);
    asc = TRUE;
}

```

```

    }
else if ( lslope1 < 0)
{
    sprintf(str,"c%.3d.d%.3d",cycle_num,orbit_num);
    asc = FALSE;
}
else
{
    if (fr.lat < 0)
    {
        sprintf(str,"c%.3d.a%.3d",cycle_num,orbit_num);
        asc=TRUE;
    }
    else
    {
        sprintf(str,"c%.3d.d%.3d",cycle_num,orbit_num);
        asc=FALSE;
    }
}

/* Check to see if point is an orbit we want and greater
   than the minimum latitude and smaller than the
   maximum latitude. If so, write to the output file. If
   the output file is not open, open it and mark it as
   being open.      */

llcmp = (dir == 1) ? fr.lat : fr.lon;

if(((asc && a[orbit_num]) || (!asc && d[orbit_num])) && (llcmp > llmin)
    && (llcmp < llmax))
{
    if (isopen == 0)
    {
        fdout = fopen(str,"a");
        isopen = 1;
    }
    if(fwrite((char *)&fr,1,REC_LEN,fdout) != REC_LEN)
    {
        geo_error(3, argv[0]);
        exit(3);
    }
}

/*
Check second point...
*/

llcmp = (dir == 1) ? fr2.lat : fr2.lon;

if(((asc && a[orbit_num]) || (!asc && d[orbit_num])) && (llcmp > llmin)
    && (llcmp < llmax))
{
    if (isopen == 0)
    {

```

```

        fdout = fopen(str,"a");
        isopen = 1;
    }
    if(fwrite((char *)&fr2,1,REC_LEN,fdout) != REC_LEN)
    {
        geo_error(3, argv[0]);
        exit(3);
    }
}

/* Read in rest of geosat data. We keep three points active
to monitor when an orbit changes from ascending to descending.
This was done because of the incomplete data at high latitudes.
*/

fr = fr2;

while(fread((char *)&fr2,1,REC_LEN,stdin) == REC_LEN)
{
    lslope2 = fr2.lat - fr.lat;

    if ((lslope1 > 0 && lslope2 <= 0) || (lslope1 < 0 && lslope2 >= 0))
    {
        /* Determine name of next orbit */

        time = fr2.utc + fr2.utcm * 1.0e-6;

        geo_cyc_orb(time, &cycle_num, &orbit_num);

        if ( lslope2 > 0 )
        {
            sprintf(str,"c%.3d.a%.3d",cycle_num,orbit_num);
            asc=TRUE;
        }
        else if ( lslope2 < 0 )
        {
            sprintf(str,"c%.3d.d%.3d",cycle_num,orbit_num);
            asc=FALSE;
        }
        else
        {
            if (fr2.lat < 0 )
            {
                sprintf(str,"c%.3d.a%.3d",cycle_num,orbit_num);
                asc=TRUE;
            }
            else
            {
                sprintf(str,"c%.3d.d%.3d",cycle_num,orbit_num);
                asc=FALSE;
            }
        }
    }
}

```

```

        }
    }

    fclose(fdout);          /* Close previous file */
    isopen = 0;
}
llcmp = (dir == 1) ? fr2.lat : fr2.lon;

if(((asc && a[orbit_num]) || (!asc && d[orbit_num])) && (llcmp > llmin)
    && (llcmp < llmax))
{
    if (isopen == 0)
    {
        fdout = fopen(str,"a");
        isopen = 1;
    }
    if(fwrite((char *)&fr2,1,REC_LEN,fdout) != REC_LEN)
    {
        geo_error(3, argv[0]);
        exit(3);
    }
}

fr = fr2;
lslope1 = lslope2;
}
}

```

Program g_repeat.c

/*

@(#)g_repeat.c 1.3 12/18/89

Program g_repeat.c

Written by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Purpose:

This program will perform a repeat track analysis
of geosat GDR's.

Method:

1. Read in all cycles
2. Calculate the mean sea surface height (m_h)
3. Subtract mean from each cycle.
4. Calculate quadratic regression and subtract from
each cycle.
5. Calculate a second regression weighted by the
inverse of the variance of the first regression.
6. Subtract new fit from each profile to obtain
final heights.
7. Calculate mean and variance.
8. Print results.

Usage:

Each GEOSAT GDR is read from a separate file.

g_repeat c???a002 > data.text

will perform a repeat track analysis from the cleaned and splined
GDR's in all available cycle for track a002.

Input:

c???a002 All cycles for the specified track cleaned
and splined.

Output:

Stdout: Data file containing the latitude, the

longitude, the mean height(m), the rms height
variance and the number of valid points for each
location of a given orbit.

c???.a002_r Data file containing the latitude, the
longitude and the residual height.

Subroutines Required:

```
-----
cr_mat_float      creates a floating point matrix.
cr_mat_double     creates a double precision matrix.
gauss_elim        solves linear system of equations.
```

References:

*/

```
# include <math.h>
# include <stdio.h>
# include "geos.h"
```

```
#define MICRO      1.e-6    /* conversion from micro-deg to deg      */
#define MILLI      1.e-2    /* conversion from centimeter to meter    */
#define MAXPOINTS  2915     /* Max point -70 to +70 degrees latitude  */
```

/*

Global Variables...

*/

```
float **h;          /* Original Heights. */
float **h_tmp;      /* Temporary Heights. */

float *mean;        /* Mean of original heights (h) */
float *mean2;       /* Mean of original heights - quad orbit corr.*/
float *mean_lon;    /* Mean of Longitudes */
float *lat;         /* Latitudes of first orbit. */
/* We don't find mean_lat because the
   latitudes are fixed in a previous
   program such as g_spline
   */

float *var;         /* Variance of original heights */
float *var2;

int *count;         /* Count for mean and var*/
int *count2;        /* Count for mean2 and var2*/

double **a, *b;     /* Used for quadratic fit*/
double *xans;       /* Used for quadratic fit */
float **quad0;      /* Keep values of quadratic fit for printing */
float **quad1;      /* Keep values of quadratic fit for printing */

int *cyc;           /* Keep track of good and bad cycles. */
int maxcyc;         /* Maximum number of good points at each
```

```

                                latitude grid point
                                */

int    i;                      /* Counter */
int    ipoint;                 /* Counter for points read in for each cycle.
                                Note: program assumes each cycle has been
                                regridded to a common grid and has the same
                                number of points.
                                */

main (argc,argv)
    int argc;
    char *argv[];
{
    /*
    Declare non-integer subroutines:
    */

    float **cr_mat_float();
    double **cr_mat_double();

    /*
    I/O file descriptors
    */

    FILE *gfile, *ofile;

    /*
    Various counters.
    */

    int iarg;
    int ipointold;
    int fill = FALSE;

    /*
    Temporary variables for calculations prior to printing.
    */

    float htmp, vtmp;
    float fit0, fit1;

    /*
    Misc. variables.
    */

    int err;                    /* Returned error message.      */
    char str[80];               /* String for filenames etc. */

    /*
    Create arrays described above...
    */

    h          = cr_mat_float(argc, MAXPOINTS);

```

```

h_tsp      = cr_mat_float(argc, MAXPOINTS);

mean       = (float *)calloc(MAXPOINTS, sizeof(float));
mean2      = (float *)calloc(MAXPOINTS, sizeof(float));
mean_lon   = (float *)calloc(MAXPOINTS, sizeof(float));
lat        = (float *)calloc(MAXPOINTS, sizeof(float));

var        = (float *)calloc(MAXPOINTS, sizeof(float));
var2       = (float *)calloc(MAXPOINTS, sizeof(float));

count      = (int *)calloc(MAXPOINTS, sizeof(int));
count2     = (int *)calloc(MAXPOINTS, sizeof(int));

cyc        = (int *)calloc(argc, sizeof(int));

a          = cr_mat_double(3,3);
b          = (double *)calloc(3, sizeof(double));
xans       = (double *)calloc(3, sizeof(double));
quad0      = cr_mat_float(argc,3);
quad1      = cr_mat_float(argc,3);

/*
Check count2 and quad1 to see if they were allocated space.  If so,
assume that all other arrays were allocated ok.
*/

if ((quad1 == NULL) || (count2 == NULL))
{
    fprintf(stderr,"%s: Unable to allocate enough storage space.\n",
            argv[0]);
    exit(1);
}

/*
Check to see if program is given arguments...
*/
if (argc == 1)
{
    fprintf(stderr,"Usage: %s c???a000 > fileout.text\n",argv[0]);
    exit(1);
}

/*
Read in all GDRs and calculate mean and variance...
iarg      is the cycle number to read in.
ipoint     is the along track point
*/

for(iarg=0; iarg<argc-1; iarg++)
{
    /*
    Open each input file...
    */

```



```

if ((gfile = fopen(argv[iarg+1], "r")) == NULL)
{
    fprintf(stderr, "%s: Unable to open file %s. Continuing...\n",
            argv[0], argv[iarg+1]);
    cyc[iarg] = BAD;
    continue; /* If there is no file, try the next file. */
}

ipoint = 0;

while (fread((char*)&fr, 1, REC_LEN, gfile) == REC_LEN)
{
    if (!fill) /* Fill latitude from first good cycle. */
    {
        lat[ipoint] = fr.lat;
    }
    else /* Check against first cycle */
    { /* to make sure points line up */
        if ((abs((int)lat[ipoint] - fr.lat) > 1000) && (fr.lat != 0))
        {
            fprintf(stderr,
                    "%s: Repeat tracks out of sync. Offending file: %s\n",
                    argv[0], argv[iarg+1]);
            exit(1);
        }
    }

    /*
     * Store Heights...
     */

    h[iarg][ipoint] = fr.m_h;

    /*
     * Set up to find mean and variances...
     */

    if ((fr.m_h != BAD) && (fr.lon != BAD))
    {
        mean[ipoint] += fr.m_h;
        var[ipoint] += fr.m_h * fr.m_h;
        count[ipoint] += 1;
        mean_lon[ipoint] += fr.lon;
    }
    ipoint++;
}

/*
 * If a cycle has no points, mark that cycle as BAD and
 * print error message.
 */

if (ipoint == 0)
{
    cyc[iarg] = BAD;
}

```

```

        ipoint = ipointold;
        fprintf(stderr,"%s: Bad file %s, no data found\n",argv[0], argv[iarg+1]);
    }
    else
    {
        ipointold = ipoint;
        fill = TRUE;
    }
}

/*
If no points were read, exit program...
*/
if ((ipoint == 0) && (ipointold == 0))
{
    fprintf(stderr,"%s: No points read, unable to perform analysis.\n", argv[0]);
    exit(1);
}
ipoint--;

/*
Find mean and variance of raw data. Also find the mean lon
at each point and determine the maximum number of cycles.
mean, var, mean_lon and maxcyc.
*/
calc_mean1();

/*
Calculate quadratic regression of difference and subtract
from each cycle...
*/
fit_quad(argc, 0);

/*
Find mean and var of h_tmp.
mean2 and var.
*/
calc_mean2();

/*
Zero mean2, var2 and count2 and
Calculate weighted regression...
*/
zero_2();
fit_quad(argc, 1);

/*
Find mean and var of h_tmp after weighted

```

```

    regression - mean2 and var.
*/

    calc_mean2();

/*
Write out residuals for each good cycle.
Concatenate "_r" to the end of the file name. This was
done instead of substitution since the user may call the
program with subdirectories - c000/c000.a002c, in which
case a prefix would change the directory name; or if the
input file does not end with an additional character -
c000.a002, substituting the last character would affect
the file name.

Output file format:

lat   lon   residual   fit0   fit1

Where the residual is h - hmean, and fit0 is
the resulting fit of the first quadratic and fit1
is the fit of the second quadratic.
*/

    for (iarg=0; iarg<argc-1; iarg++)
    {
        if(cyc[iarg] != BAD)
        {
            strcpy(str,argv[iarg+1]);
            strcat(str,"_r");
            if ((ofile = fopen(str, "w")) == NULL)
            {
                fprintf(stderr,"%s: Unable to open file %s. Continuing...\n",
                    argv[0], str);
                continue;      /* Try next file.      */
            }

            for (i=0; i<ipoint; i++)
            {
                if((h_tmp[iarg][i] != BAD) && (mean2[i] != BAD))
                {
                    htmp = (h_tmp[iarg][i]-mean2[i])*MILLI;
                }
                else
                {
                    htmp = BAD*MILLI;
                }
                fit0 = (quad0[iarg][0] + (quad0[iarg][1]+quad0[iarg][2]*lat[i])
                    *lat[i])*MILLI;
                fit1 = (quad1[iarg][0] + (quad1[iarg][1]+quad1[iarg][2]*lat[i])
                    *lat[i])*MILLI;
                fprintf(ofile,"%4d\t%8.4f\t%8.4f\t%8.4f\t%8.4f\n", i,
                    lat[i]*MICRO, mean_lon[i]*MICRO, htmp, fit0, fit1);
            }
        }
    }

```

```

        fclose(ofile);
    }

}

/*
Write out statistics to standard output.
The output is:

i      lat      mean_lon      mean2      var      var2      count2

Where i is the sequential point number, lat is the latitude
at that point, mean_lon is the mean_lon, mean2 is the mean height
with orbit error etc removed, var is the variance, var2 is the sum
of squares and count2 is the number of cycles that went into the
statistics...
*/
for (i=0; i<ipoint; i++)
{
    if (mean2[i] != BAD)
    {
        vtmp = sqrt(var[i])*MILLI;
    }
    else
    {
        vtmp = BAD*MILLI;
    }

    fprintf(stdout,"%4d\t%8.4f\t%8.4f\t%8.4f\t%8.4f\t%12.4f\t%3d\n",
        i, lat[i]*MICRO, mean_lon[i]*MICRO, mean2[i]*MILLI,
        vtmp, var2[i], count2[i]);
}
fclose(str);
}

/*-----
Subprogram calc_mean1()

Written by: Michael Caruso
           Woods Hole Oceanographic Institution

Purpose: This subprogram is used with g_repeat
         to calculate the means of input data.
-----*/
calc_mean1()
{
    maxcyc = 0;

    for (i=0; i<ipoint; i++)
    {
        if (count[i] > 1)          /* Check for at least two good points. */
        {
            mean[i] /= count[i];
            mean_lon[i] /= count[i];

```

```

        var[i] = var[i]/count[i] - mean[i]*mean[i];
        maxcyc = (count[i] > maxcyc) ? count[i] : maxcyc;
    }
    else
    {
        mean[i] = BAD;
        var[i] = BAD;
    }
}
}

```

```

/*-----
Subprogram calc_mean2()

Written by: Michael Caruso
           Woods Hole Oceanographic Institution

Purpose:  This subprogram is used with g_repeat
           to calculate the means of temp data.
-----*/

```

```

calc_mean2()
{
    for (i=0; i<ipoint; i++)
    {
        if (count2[i] > 1)      /* Check for at least two good points */
        {
            mean2[i] /= count2[i];
            var[i] = var2[i]/count2[i] - mean2[i]*mean2[i];
        }
        else
        {
            mean2[i] = BAD;
            var[i] = BAD;
        }
    }
}

```

```

/*-----
Subprogram fit_quad()

Written by: Michael Caruso
           Woods Hole Oceanographic Institution

Purpose:  This subprogram is used with g_repeat
           to fit a quadratic to an arc.

Method:  fit a quadratic in a least squares sense..

```

```

      num      x      xx
a =  x      xx      xxx
      xx      xxx      xxxx

      y      - z

```

```

b =  xy - xz
    xxy - xxz

```

```

-----*/

```

```

fit_quad(numcyc, pass)
    int numcyc;
    int pass;
{
    int iarg;
    double x, y, z, xx, xy, xz, xxx, xxy, xxz, xxxx;
    double t, t2, t3, t4;
    int err;
    int num;

    for (iarg=0; iarg<numcyc-1; iarg++)
    {
        if(cyc[iarg] != BAD)
        {
            /*
             Declare dummy arrays for procedure...
             And set to zero.
            */
            num = 0;
            x = y = z = xx = xy = xz = xxx = xxy = xxz = xxxx = 0.0;

            for (i=0; i<ipoint; i++)
            {
                if (h[iarg][i] != BAD)
                {
                    if (count[i] >= maxcyc/2)
                    {
                        if (!pass)
                        {
                            t      = lat[i];
                            t2     = t*t;
                            t3     = t2*t;
                            t4     = t3*t;
                            x      += t;
                            y      += h[iarg][i];
                            z      += mean[i];
                            xx     += t2;
                            xy     += t*h[iarg][i];
                            xz     += t*mean[i];
                            xxx    += t3;
                            xxy    += t2*h[iarg][i];
                            xxz    += t2*mean[i];
                            xxxx   += t4;
                            num++;
                        }
                    }
                    else
                    {
                        if (var[i] != BAD)
                        {

```

```

        t      = lat[i];
        t2     = t*t;
        t3     = t2*t;
        t4     = t3*t;
        x      += t/var[i];
        y      += h[iarg][i]/var[i];
        z      += mean[i]/var[i];
        xx     += t2/var[i];
        xy     += t*h[iarg][i]/var[i];
        xz     += t*mean[i]/var[i];
        xxx    += t3/var[i];
        xxy    += t2*h[iarg][i]/var[i];
        xxz    += t2*mean[i]/var[i];
        xxxx   += t4/var[i];
        num++;
    }
}
}
}
}

/*
If we have less than three points, label bad cycle
*/
    if (num < 3)
    {
        cyc[iarg] = BAD;
        continue;
    }

/*
Set up matrices and solve x*xans=b...
*/
    a[0][0] = num;
    a[0][1] = a[1][0] = x;
    a[0][2] = a[1][1] = a[2][0] = xx;
    a[1][2] = a[2][1] = xxx;
    a[2][2] = xxxx;
    b[0] = y-z;
    b[1] = xy-xz;
    b[2] = xxy-xxz;

    err = gauss_elim(a, 3, 3, b, xans);

/*
Save fit parameters for later printing...
*/
    for (i=0; i<3; i++)
    {
        if(pass == 0)
        {
            quad0[iarg][i] = xans[i];
        }
    }

```

```

        else
        {
            quadri[iarg][i] = xans[i];
        }
    }

/*
Subtract regression from each cycle...
Put result into h_tmp and keep track of
data for mean and variance calculation - calc_mean2.
*/

    for(i=0; i<ipoint; i++)
    {
        if(h[iarg][i] != BAD)
        {
            h_tmp[iarg][i] = h[iarg][i]-xans[0]-
                (xans[1]+xans[2]*lat[i])*lat[i];
            mean2[i] += h_tmp[iarg][i];
            var2[i] += h_tmp[iarg][i]*h_tmp[iarg][i];
            count2[i] += 1;
        }
        else
        {
            h_tmp[iarg][i] = BAD;
        }
    }
}

}

}

/*-----
Subprogram zero_2()

Written by: Michael Caruso
           Woods Hole Oceanographic Institution

Purpose: This subprogram is used with g_repeat
         to zero mean2 var2 and count2
-----*/
zero_2()
{
    for (i=0; i<ipoint; i++)
    {
        mean2[i] = var2[i] = 0.0;
        count2[i] = 0;
    }
}

```


Program g_repeats.c

/*

@(#)g_repeats.c 1.2 4/25/90

Written by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Purpose:

This program will perform a repeat track analysis
of geosat GDR's.

Method:

1. Read in all cycles
2. Calculate the mean sea surface height (m_h)
3. Subtract mean from each cycle.
4. Calculate sine regression and subtract from
each cycle.
5. Calculate a second regression weighted by the
inverse of the variance of the first regression.
6. Subtract new fit from each profile to obtain
final heights.
7. Calculate mean and variance.
8. Print results.

Usage:

Each GEOSAT GDR is read from a separate file.

g_repeat c???a002 > data.text

will perform a repeat track analysis from the cleaned and splined
GDR's in all available cycle for track a002.

Input:

c???a002 All cycles for the specified track cleaned
 and splined.

Output:

Stdout: Data file containing the latitude, the
 longitude, the mean height(m), the rms height
 variance and the number of valid points for each
 location of a given orbit.

c???a002_r Data file containing the latitude, the
 longitude and the residual height.

Subroutines Required:

```
-----
cr_mat_float      creates a floating point matrix.
cr_mat_double     creates a double precision matrix.
gauss_elim        solves linear system of equations.
```

References:

*/

```
# include <math.h>
# include <stdio.h>
# include "geos.h"
```

```
#define MICRO      1.e-6   /* conversion from micro-deg to deg      */
#define MILLI      1.e-2   /* conversion from centimeter to meter */
#define MAXPOINTS  2915    /* Max point -70 to +70 degrees latitude */
```

```
#define DEG_TO_RAD  M_PI/180.0   /* Conversion to radians */
#define OM          2.0*M_PI/PERIOD /* Orbital Omega */
#define M_2PI       2.0*M_PI     /* 2 * PI */
```

```
/*
   Global Variables...
*/
```

```
float **h;           /* Original Heights. */
float **h_tmp;       /* Temporary Heights. */
double **times;      /* Array of times for each GDR */
```

```
float *mean;         /* Mean of original heights (h) */
float *mean2;        /* Mean of original heights - quad orbit corr.*/
float *mean_lon;     /* Mean of Longitudes */
float *lat;          /* Latitudes of first orbit. */
/* We don't find mean_lat because the
   latitudes are fixed in a previous
   program such as g_spline
*/
```

```
float *var;          /* Variance of original heights */
float *var2;
```

```
int *count;          /* Count for mean and var*/
int *count2;         /* Count for mean2 and var2*/
```

```
double **a, *b;      /* Used for quadratic fit*/
double *xans;         /* Used for quadratic fit */
float **quad0;        /* Keep values of quadratic fit for printing */
float **quad1;        /* Keep values of quadratic fit for printing */
```

```

int *cyc;          /* Keep track of good and bad cycles. */
int maxcyc;        /* Maximum number of good points at each
                    latitude grid point
                    */

int    i;          /* Counter */
int    ipoint;     /* Counter for points read in for each cycle.
                    Note: program assumes each cycle has been
                    regridded to a common grid and has the same
                    number of points.
                    */

main (argc,argv)
    int argc;
    char *argv[];
{
    /*
    Declare non-integer subroutines:
    */

    float **cr_mat_float();
    double **cr_mat_double();

    /*
    I/O file descriptors
    */

    FILE *gfile, *ofile;

    /*
    Various counters.
    */

    int iarg;
    int ipointold;
    int fill = FALSE;

    /*
    Temporary variables for calculations prior to printing.
    */

    float htmp, vtmp;
    float fit0, fit1;
    float t;

    /*
    Misc. variables.
    */

    int err;          /* Returned error message. */
    char str[80];     /* String for filenames etc. */

    /*

```

```

    Create arrays described above...
*/
h          = cr_mat_float(argc, MAXPOINTS);
h_tmp      = cr_mat_float(argc, MAXPOINTS);
times      = cr_mat_double(argc, MAXPOINTS);

mean       = (float *)calloc(MAXPOINTS, sizeof(float));
mean2      = (float *)calloc(MAXPOINTS, sizeof(float));
mean_lon   = (float *)calloc(MAXPOINTS, sizeof(float));
lat        = (float *)calloc(MAXPOINTS, sizeof(float));

var        = (float *)calloc(MAXPOINTS, sizeof(float));
var2       = (float *)calloc(MAXPOINTS, sizeof(float));

count      = (int *)calloc(MAXPOINTS, sizeof(int));
count2     = (int *)calloc(MAXPOINTS, sizeof(int));

cyc        = (int *)calloc(argc, sizeof(int));

a          = cr_mat_double(3,3);
b          = (double *)calloc(3, sizeof(double));
xans       = (double *)calloc(3, sizeof(double));
quad0      = cr_mat_float(argc,3);
quad1      = cr_mat_float(argc,3);

/*
Check count2 and quad1 to see if they were allocated space.  If so,
assume that all other arrays were allocated ok.
*/

if ((quad1 == NULL) || (count2 == NULL))
{
    fprintf(stderr,"%s: Unable to allocate enough storage space.\n",
            argv[0]);
    exit(1);
}

/*
Check to see if program is given arguments...
*/
if (argc == 1)
{
    fprintf(stderr,"Usage: %s c??? a000 > fileout.text\n",argv[0]);
    exit(1);
}

/*
Read in all GDRs and calculate mean and variance...
iarg      is the cycle number to read in.
ipoint     is the along track point
*/

for(iarg=0; iarg<argc-1; iarg++)

```

```

{
    /*
    Open each input file...
    */
    if ((gfile = fopen(argv[iarg+1], "r")) == NULL)
    {
        fprintf(stderr, "%s: Unable to open file %s. Continuing...\n",
            argv[0], argv[iarg+1]);
        cyc[iarg] = BAD;
        continue; /* If there is no file, try the next file. */
    }

    ipoint = 0;

    while (fread((char*)&fr, 1, REC_LEN, gfile) == REC_LEN)
    {
        if (!fill) /* Fill latitude from first good cycle. */
        {
            lat[ipoint] = fr.lat;
        }
        else /* Check against first cycle */
        {
            /* to make sure points line up */
            if ((abs((int)lat[ipoint] - fr.lat) > 1000) && (fr.lat != 0))
            {
                fprintf(stderr,
                    "%s: Repeat tracks out of sync. Offending file: %s\n",
                    argv[0], argv[iarg+1]);
                exit(1);
            }
        }

        /*
        Store Heights and times...
        Note: Subtract time zero to keep times small.
        */

        h[iarg][ipoint] = fr.m_h;
        times[iarg][ipoint] = (fr.utc + fr.utcm * MICRO) - TIME_ZERO;

        /*
        Set up to find mean and variances...
        */

        if ((fr.m_h != BAD) && (fr.lon != BAD))
        {
            mean[ipoint] += fr.m_h;
            var[ipoint] += fr.m_h * fr.m_h;
            count[ipoint] += 1;
            mean_lon[ipoint] += fr.lon;
        }
        ipoint++;
    }
}

```

```

/*
    If a cycle has no points, mark that cycle as BAD and
    print error message.
*/
    if(ipoint == 0)
    {
        cyc[iarg] = BAD;
        ipoint = ipointold;
        fprintf(stderr,"%s: Bad file %s, no data found\n",argv[0],
            argv[iarg+1]);
    }
    else
    {
        ipointold = ipoint;
        fill = TRUE;
    }

}

/*
    If no points were read, exit program...
*/
if ((ipoint == 0) && (ipointold == 0))
{
    fprintf(stderr,"%s: No points read, unable to perform analysis.\n",
        argv[0]);
    exit(1);
}
ipoint--;

/*
    Find mean and variance of raw data. Also find the mean lon
    at each point and determine the maximum number of cycles.
    mean, var, mean_lon and maxcyc.
*/

    calc_mean1();

/*
    Calculate quadratic regression of difference and subtract
    from each cycle...
*/

    fit_sin(argc, 0);

/*
    Find mean and var of h_tmp.
    mean2 and var.
*/
    calc_mean2();

/*
    Zero mean2, var2 and count2 and

```

```

    Calculate weighted regression...
*/

    zero_2();
    fit_sin(argc, 1);

/*
    Find mean and var of h_tmp after weighted
    regression - mean2 and var.
*/

    calc_mean2();

/*
    Write out residuals for each good cycle.
    Concatenate "_r" to the end of the file name. This was
    done instead of substitution since the user may call the
    program with subdirectories - c000/c000.a002c, in which
    case a prefix would change the directory name; or if the
    input file does not end with an additional character -
    c000.a002, substituting the last character would affect
    the file name.

    Output file format:

    lat   lon   residual   fit0   fit1

    Where the residual is h - hmean, and fit0 is
    the resulting fit of the first quadratic and fit1
    is the fit of the second quadratic.
*/

    for (iarg=0; iarg<argc-1; iarg++)
    {
        if(cyc[iarg] != BAD)
        {
            strcpy(str,argv[iarg+1]);
            strcat(str,"_r");
            if ((ofile = fopen(str, "w")) == NULL)
            {
                fprintf(stderr,"%s: Unable to open file %s. Continuing...\n",
                    argv[0], str);
                continue;      /* Try next file.      */
            }

            for (i=0; i<ipoint; i++)
            {
                if((h_tmp[iarg][i] != BAD) && (mean2[i] != BAD))
                {
                    htmp = (h_tmp[iarg][i]-mean2[i])*MILLI;
                    t = remainder(OM*times[iarg][i], M_2PI);
                    fit0 = (quad0[iarg][0] + quad0[iarg][1]*cos(t) +
                        quad0[iarg][2]*sin(t))*MILLI;

```

```

        fit1 = (quad1[iarg][0] + quad1[iarg][1]*cos(t) +
                quad1[iarg][2]*sin(t))*MILLI;
    }
    else
    {
        htmp = BAD*MILLI;
        fit0 = fit1 = BAD;
    }
    fprintf(ofile,"%4d\t%8.4f\t%8.4f\t%8.4f\t%8.4f\t%8.4f\n", i,
            lat[i]*MICRO, mean_lon[i]*MICRO, htmp, fit0, fit1);
}
fclose(ofile);
}

}

/*
Write out statistics to standard output.
The output is:

i      lat      mean_lon      mean2      var      var2      count2

Where i is the sequential point number, lat is the latitude
at that point, mean_lon is the mean_lon, mean2 is the mean height
with orbit error etc removed, var is the variance, var2 is the sum
of squares and count2 is the number of cycles that went into the
statistics...
*/
for (i=0; i<ipoint; i++)
{
    if (mean2[i] != BAD)
    {
        vtmp = sqrt(var[i])*MILLI;
    }
    else
    {
        vtmp = BAD*MILLI;
    }

    fprintf(stdout,"%4d\t%8.4f\t%8.4f\t%8.4f\t%8.4f\t%12.4f\t%3d\n",
            i, lat[i]*MICRO, mean_lon[i]*MICRO, mean2[i]*MILLI,
            vtmp, var2[i], count2[i]);
}
fclose(str);
}

/*-----
Subprogram calc_mean1()

Written by: Michael Caruso
           Woods Hole Oceanographic Institution

Purpose: This subprogram is used with g_repeat
to calculate the means of input data.

```



```

-----*/
calc_mean1()
{
    maxcyc = 0;

    for (i=0; i<ipoint; i++)
    {
        if (count[i] > 1)          /* Check for at least two good points. */
        {
            mean[i] /= count[i];
            mean_lon[i] /= count[i];
            var[i] = var[i]/count[i] - mean[i]*mean[i];
            maxcyc = (count[i] > maxcyc) ? count[i] : maxcyc;
        }
        else
        {
            mean[i] = BAD;
            var[i] = BAD;
        }
    }
}

```

```

/*-----
Subprogram calc_mean2()

Written by: Michael Caruso
           Woods Hole Oceanographic Institution

Purpose: This subprogram is used with g_repeat
         to calculate the means of temp data.
-----*/

```

```

calc_mean2()
{
    for (i=0; i<ipoint; i++)
    {
        if (count2[i] > 1)          /* Check for at least two good points */
        {
            mean2[i] /= count2[i];
            var[i] = var2[i]/count2[i] - mean2[i]*mean2[i];
        }
        else
        {
            mean2[i] = BAD;
            var[i] = BAD;
        }
    }
}

```

```

/*-----
Subprogram fit_sin()

Written by: Michael Caruso
           Woods Hole Oceanographic Institution

```

Purpose: This subprogram is used with g_repeat
to fit a sin to an arc.

Method: fit a sin in a least squares sense..

```

num      x      xx
a =  x      xxx     xxxx
      xx      xxxx     xxxxx

```

```

y      - z
b =  xy - xz
      xxy - xxz

```

```

-----*/
fit_sin(numcyc, pass)
    int numcyc;
    int pass;
{
    double x, y, z, xx, xy, xz, xxx, xxy, xxz, xxxx, xxxxx;
    double t;          /* Variable to fit to */
    double sin_t, cos_t; /* Sin(t), Cos(t) */

    int iarg;
    int err;
    int num;

    for (iarg=0; iarg<numcyc-1; iarg++)
    {
        if(cyc[iarg] != BAD)
        {
            /*
             Declare dummy arrays for procedure...
             And set to zero.
            */
            num = 0;
            x = y = z = xx = xy = xz = xxx = xxy = xxz = xxxx = xxxxx = 0.0;

            for (i=0; i<ipoint; i++)
            {
                if (h[iarg][i] != BAD)
                {
                    if (count[i] >= maxcyc/2)
                    {
                        if (!pass)
                        {
                            t
                                = remainder(OM*times[iarg][i], M_2PI);
                            cos_t
                                = cos(t);
                            sin_t
                                = sin(t);
                            x
                                += cos_t;
                            y
                                += h[iarg][i];
                            z
                                += mean[i];
                            xx
                                += sin_t;

```

```

        xy      += cos_t*h[iarg][i];
        xz      += cos_t*mean[i];
        xxx     += cos_t*cos_t;
        xxy     += sin_t*h[iarg][i];
        xxz     += sin_t*mean[i];
        xxxx    += cos_t*sin_t;
        xxxxx   += sin_t*sin_t;
        num++;
    }
else
{
    if (var[i] != BAD)
    {
        t      = remainder(OM*times[iarg][i],
                           M_2PI);

        cos_t  = cos(t);
        sin_t  = sin(t);
        x      += cos_t/var[i];
        y      += h[iarg][i]/var[i];
        z      += mean[i]/var[i];
        xx     += sin_t/var[i];
        xy     += cos_t*h[iarg][i]/var[i];
        xz     += cos_t*mean[i]/var[i];
        xxx    += cos_t*cos_t/var[i];
        xxy    += sin_t*h[iarg][i]/var[i];
        xxz    += sin_t*mean[i]/var[i];
        xxxx   += cos_t*sin_t/var[i];
        xxxxx  += sin_t*sin_t/var[i];
        num++;
    }
}
}
}
}

/*
If we have less than three points, label bad cycle
*/
    if (num < 3)
    {
        cyc[iarg] = BAD;
        continue;
    }

/*
Set up matrices and solve x*xans=b...
*/
    a[0][0] = num;
    a[0][1] = a[1][0] = x;
    a[0][2] = a[2][0] = xx;
    a[1][1] = xxx;
    a[1][2] = a[2][1] = xxxx;
    a[2][2] = xxxxx;
    b[0] = y-z;

```

```

        b[1] = xy-xz;
        b[2] = xxy-xxz;

        err = gauss_elim(a, 3, 3, b, xans);

/*
  Save fit parameters for later printing...
  */

        for (i=0; i<3; i++)
        {
            if(pass == 0)
            {
                quad0[iarg][i] = xans[i];
            }
            else
            {
                quad1[iarg][i] = xans[i];
            }
        }

/*
  Subtract regression from each cycle...
  Put result into h_tmp and keep track of
  data for mean and variance calculation - calc_mean2.
  */

        for(i=0; i<ipoint; i++)
        {
            if(h[iarg][i] != BAD)
            {
                t = remainder(OM*times[iarg][i], M_2PI);
                h_tmp[iarg][i] = h[iarg][i]-xans[0]-xans[1]*cos(t)-
                    xans[2]*sin(t);
                mean2[i] += h_tmp[iarg][i];
                var2[i] += h_tmp[iarg][i]*h_tmp[iarg][i];
                count2[i] += 1;
            }
            else
            {
                h_tmp[iarg][i] = BAD;
            }
        }
    }
}

/*-----
Subprogram zero_2()

Written by: Michael Caruso
           Woods Hole Oceanographic Institution

Purpose: This subprogram is used with g_repeat
         to zero mean2 var2 and count2

```

```
-----*/  
zero_2()  
{  
    for (i=0; i<ipoint; i++)  
    {  
        mean2[i] = var2[i] = 0.0;  
        count2[i] = 0;  
    }  
}
```

Program g_seporb.c

/*

@(#)g_seporb.c 1.4 6/14/90

Written by:

Michael Caruso

Woods Hole Oceanographic Institution

Woods Hole, MA

Modifications:

12-15-89 MC Changed call to geo_cyc_orb so that time is
 passed and not a GDR.

Purpose:

Read raw GEOSAT GDR and splits data into separate orbits. Each orbit is defined as beginning at the northernmost point of a track. Each orbit is further separated into an ascending section and a descending section. Orbits are then written out to separate files of the form:

 cmmmm.annn or cmmmm.nnnd

where

| | |
|------|-------------------------------------|
| mmmm | is the cycle number, |
| nnn | is the orbit number for that cycle, |
| a | signifies ascending portion, |
| d | signifies descending portion. |

The data is written out in the same form as it was read in. This is consecutive records of 78 bytes each. The last point of an ascending or descending orbit is the most northern or most southern point of that orbit.

Method:

Reads raw GEOSAT GDR from standard input. Calculates correct filename using convention shown above. Tests to see when slope of lat/lon track changes sign which indicates change from ascending to descending or descending to ascending part of orbit.

Usage:

The data is read from standard input such as direct from the NODC data tapes:

dd if=/dev/rmt8 ibs=16380 files=34 | g_seporb

This would separate all the files into the correct orbits.

NOTE: input file must have at least two points.

Input:

Stdin Raw Geosat GDRs.

Output:

c???.???? Separated GEOSAT data.

Subroutines Required:

geo_cyc_orb Returns the cycle number and orbit_number
 for a given time.

geo_error Prints error messages.

*/

```
#include <stdio.h>
#include <sys/file.h>
#include <math.h>
#include "geos.h"
```

```
main(argc, argv)
    int argc;
    char *argv[];
{
```

```
    struct frame fr2;
```

```
    char str[80];
```

```
    short int orbit_num_tot;
    int cycle_num;
    int orbit_num;
    long int lslope1, lslope2;
```

```
    double time;
```

```
    FILE *fdout;
```

```
    /* read initial data record... */
```

```
    if(fread((char *)&fr, 1, REC_LEN, stdin) != REC_LEN)
    {
        geo_error(3, argv[0]);
        exit(1);
    }
```

```
    /* read second data record... */
```

```
    if(fread((char *)&fr2, 1, REC_LEN, stdin) != REC_LEN)
    {
```

```

        geo_error(3, argv[0]);
        exit(1);
    }

    /* Determine name of first orbit */

    time = fr.utcm + fr.utcm*1.0e-6;
    lslope1 = fr2.lat - fr.lat;

    geo_cyc_orb(time, &cycle_num, &orbit_num);

    if ( lslope1 > 0 )    /* If lslope1 > 0 ascending orbit else descending */
        sprintf(str,"c%.3d.a%.3d",cycle_num,orbit_num);
    else if ( lslope1 < 0 )
        sprintf(str,"c%.3d.d%.3d",cycle_num,orbit_num);
    else
    {
        if (fr.lat < 0)
        {
            sprintf(str,"c%.3d.a%.3d",cycle_num,orbit_num);
        }
        else
        {
            sprintf(str,"c%.3d.d%.3d",cycle_num,orbit_num);
        }
    }

    fdout = fopen(str,"a");    /* open a new file or append an old */

    /* Write out first two records to opened file... */

    if(fwrite((char *)&fr, 1, REC_LEN, fdout) != REC_LEN)
    {
        geo_error(3, argv[0]);
        exit(3);
    }

    if(fwrite((char *)&fr2, 1, REC_LEN, fdout) != REC_LEN)
    {
        geo_error(3, argv[0]);
        exit(3);
    }

    /* Read in rest of geosat data */

    fr = fr2;

    while(fread((char *)&fr2, 1, REC_LEN, stdin) == REC_LEN)
    {
        lslope2 = fr2.lat - fr.lat;

        if ((lslope1 > 0 && lslope2 <= 0) || (lslope1 < 0 && lslope2 >= 0))
        {
            /* Determine name of next orbit */

```



```

time = fr2.utc + fr2.utcm * 1.0e-6;

geo_cyc_orb(time, &cycle_num, &orbit_num);

if ( lslope2 > 0 )
    sprintf(str,"c%.3d.a%.3d",cycle_num,orbit_num);
else if ( lslope2 < 0)
    sprintf(str,"c%.3d.d%.3d",cycle_num,orbit_num);
else
{
    if (fr.lat < 0)
    {
        sprintf(str,"c%.3d.a%.3d",cycle_num,orbit_num);
    }
    else
    {
        sprintf(str,"c%.3d.d%.3d",cycle_num,orbit_num);
    }
}
fclose(fdout);          /* Close previous file */
fdout = fopen(str,"a");  /* Open new or append file*/
}

if(fwrite((char *)&fr2, 1, REC_LEN, fdout) != REC_LEN)
{
    geo_error(3, argv[0]);
    exit(3);
}

fr      = fr2;
lslope1 = lslope2;
}

}

```

Program g_spike.c

/*

@(#)g_spike.c 1.4 11/14/89

Program g_spike.c

Written by:

Michael Caruso

Woods Hole Oceanographic Institution

Woods Hole, MA

Purpose:

This program will remove spikes from data by a series of quadratic fits.

Method:

1. Break data into continuous segments
2. Fit each segment with a quadratic
3. If fit is within outlier, keep point else, remove two worst points and fit segment with another quadratic.
4. If fit is within outlier, keep point else, calculate a linear fit.
5. If linear fit is within outlier, keep point. Else reject point as bad
6. Delete points that do not have enough neighbors and segments that do not have enough points.

Usage:

The GEOSAT GDR is read from standard input.

cat c000.a002 | g_spike deltax neighbors outlier > c000.a002s

will remove the spike records from the GDR in c000.a002.

Input:

| | |
|-----------|--|
| Stdin | Clean GEOSAT GDRs |
| deltmax | Seconds that define gap in record |
| neighbors | Number of neighbors required for spline. |
| outliers | Centimeters for rejection of point after spline fit. |

Output:

Stdout: GEOSAT GDRs with spikes removed.

Subroutines Required:

gauss_elim Solves linear equation $Ax=b$ by Gaussian Elimination.

Subprograms Required:

comp_fit_quad Computes quadratic least squares fit.

comp_fit_lin Computes linear least squares fit.

find_bad_pts Finds two worst points in segment.

write_gdr Writes a single GDR to stdout or prints error.

References:

```
*/
# include <math.h>
# include <stdio.h>
# include "geos.h"

#define NUMARGS       3
#define DARG           1
#define NARG           2
#define OARG           3
#define MICRO         1e-6         /* Conv for utcm                 */
#define BADFIT         -99999.0       /* Return if least sq malformed */

#define SWAP(u,v) {(xswap)=(u);(u)=(v);(v)=(xswap);}

double **a, *b;                 /* Arrays for quad fit */
double **a1, *b1;               /* Arrays for linear fit */
double *xans, *xans1;           /* Results for quad and linear fit */
struct frame frs[3000];         /* GDRs */
short int kstart, kstop;        /* Start and stop for each fit */
double max0, max1;               Two worst points to remove */
int imax0, imax1;               /* if first fit is bad         */
double *h_fit;                 /* Temp array of fits for find_bad_pts */
double t;                        /* Temp time variable */

int num;                         /* Number of points in fit segment */
double xswap;                    /* Temp swap variable         */

main (argc,argv)
int argc;
char *argv[];
{

/*
Declare subroutines and subprograms...
```

```

*/
double      **cr_mat_double();
double      comp_fit_quad();
double      comp_fit_lin();
int         find_bad_pts();
int         write_gdr();

int err;                      /* error returned by gauss_elim */
int neighbors;

double time1, time2;          /* Read in times for gap determination */
double h_new;                  /* Calculated height */

float deltax;                  /* Maximum time for gap */
float outlier;                 /* Maximum offset for rejected point */

short int seg_len[1000];      /* defines each segment */
short int seg_beg[1000];      /*

short int points=0;           /* Counters */
short int segments = 0;       /*
short int i, j, k, ii;        /*

/*
Check arguments...
*/

if ((argc != NUMARGS+1) && (argc != 1))
{
    fprintf(stderr, "Usage: %s [deltmax deighbors outlier] < filein > filout\n",
        argv[0]);
    exit(1);
}
if (argc == NUMARGS+1)
{
    sscanf(argv[DARG], "%f", &deltmax);
    sscanf(argv[NARG], "%d", &neighbors);
    sscanf(argv[OARG], "%f", &outlier);
}
else
{
    {
        deltax    = 3.3;
        neighbors = 13;
        outlier    = 50.0;
    }
}

/*
set up matrices for least squares...
*/
a      = cr_mat_double(3,3);

```

```

a1    = cr_mat_double(2,2);
b     = (double *)calloc(3, sizeof(double));
b1    = (double *)calloc(2, sizeof(double));
xans  = (double *)calloc(3, sizeof(double));
xans1 = (double *)calloc(2, sizeof(double));

h_fit = (double *)calloc(neighbors, sizeof(double));

/*
  Read in all GDRs...
*/
while (fread((char*)&frs[points],1,REC_LEW,stdin)==REC_LEW) points++;
points--;

/*
  1. Break into data segments...
*/
seg_len[0] = 1;
seg_beg[0] = 0;
time2 = frs[0].utc + frs[0].utcm*MICRO;
for (i=0; i<points; i++)
{
    time1 = time2;
    time2 = frs[i+1].utc + frs[i+1].utcm*MICRO;

    if ((time2 - time1) <= deltax)
    {
        seg_len[segments]++;
    }
    else
    {
        segments++;
        seg_beg[segments] = i + 1;
        seg_len[segments] = 1;
    }
}

if (seg_len[0] == 0) exit(1);

/*
  2. For each segment...
*/
for (i=0; i<=segments; i++)
{
    /*
      2a. Ignore segment if there are too few
      points...
    */
    if (seg_len[i] < neighbors) continue;
    /*
      2b. Fit a quadratic through each point...
    */

```

```

    */
else
{
    for (j=seg_beg[i]; j<seg_beg[i]+seg_len[i]; j++)
    {
        kstart = j - neighbors/2;
        kstop  = kstart + neighbors;
        imax0 = imax1 = -1;

        h_new = comp_fit_quad(j);

/*
    3. If fit is tolerable write out point...
*/
        if((fabs(h_new-frs[j].m_h) < outlier)
            && (h_new != BADFIT))
        {
            write_gdr(j, argv[0]);
        }

/*
    3a. Else remove two worst points and recompute fit...
        If fit is malformed, remove first and last point and recompute fit...
*/
        else
        {
            if (h_new == BADFIT)
            {
                imax0 = 0;
                imax1 = num - 1;
            }
            else
                find_bad_pts();

            /*
                Recompute fit...
            */

            h_new = comp_fit_quad(j);

/*
    4. If fit is tolerable write out point...
*/
            if((fabs(h_new-frs[j].m_h) < outlier)
                && (h_new != BADFIT))
            {
                write_gdr(j, argv[0]);
            }
            else
            {
                h_new = comp_fit_lin(j);
                t = frs[j].utc + frs[j].utcm*MICRO;

```



```

        t = frs[k].utc + frs[k].utcm*MICRO;
        t2 = t*t;
        t3 = t2*t;
        t4 = t3*t;
        x += t;
        y += frs[k].m_h;
        xx += t2;
        xy += t*frs[k].m_h;
        xxx += t3;
        xxy += t2*frs[k].m_h;
        xxxx += t4;
        num ++;
    }

}

a[0][0]      = num;
a[0][1]      = a[1][0] = x;
a[0][2]      = a[1][1] = a[2][0] = xx;
a[1][2]      = a[2][1] = xxx;
a[2][2]      = xxxx;
b[0]         = y;
b[1]         = xy;
b[2] = xxy;

err = gauss_elim(a, 3, 3, b, xans);

t = frs[j].utc + frs[j].utcm*MICRO;
h_new = xans[0] + xans[1]*t + xans[2]*t*t;

if (err == 0)
    return(h_new);
else
    return(BADFIT);
}

/*-----
Subprogram comp_fit_lin

Written by: Michael Caruso
           Woods Hole Oceanographic Institution

Purpose:   This subprogram is used with g_spline to
           compute a linear least squares fit.
-----*/

double
comp_fit_lin(j, prog)
int j;
char *prog;
{
    double x, y, xx, xy;
    double h_new, t, t2, t3, t4;
    int err;

```



```

int k;

x = y = xx = xy = 0.0;
num = 0;

for (k= kstart; k< kstop; k++)
{
    if((k != (kstart+imax0)) && (k != (kstart+imax1))
        && (k != j))
    {
        t = frs[k].utc + frs[k].utcm*MICRO;
        t2 = t*t;
        x += t;
        y += frs[k].m_h;
        xx += t2;
        xy += t*frs[k].m_h;
        num++;
    }
}

a1[0][0] = num;
a1[0][1] = a1[1][0] = x;
a1[1][1] = xx;

b1[0] = y;
b1[1] = xy;

err = gauss_elim(a1, 2, 2, b1, xans1);

t = frs[j].utc + frs[j].utcm*MICRO;
h_new = xans1[0] + xans1[1]*t;
if (err == 0)
    return (h_new);
else
    return (BADFIT);
}
/*-----
Subprogram find_bad_pts

Written by:  Michael Caruso
            Woods Hole Oceanographic Institution

Purpose:
            This subprogram finds the two worst points
            in a series for program g_spike.
-----*/
find_bad_pts()
{
    short int ii;

    for (ii=0; ii<num; ii++)
    {
        t = frs[kstart+ii].utc + frs[kstart+ii].utcm*MICRO;
        h_fit[ii] = frs[kstart+ii].m_h - (xans[0]+xans[1]*t + xans[2]*t*t);
    }
}

```

```

    }
    if (fabs(h_fit[0]) > fabs(h_fit[1]))
    {
        max0 = fabs(h_fit[0]);
        max1 = fabs(h_fit[1]);
        imax0 = 0;
        imax1 = 1;
    }
    else
    {
        max0 = fabs(h_fit[1]);
        max1 = fabs(h_fit[0]);
        imax0 = 1;
        imax1 = 0;
    }
    for (ii=2; ii<num; ii++)
    {
        if(fabs(h_fit[ii]) > max1)
        {
            max1 = fabs(h_fit[ii]);
            imax1 = ii;
        }
        if (max1 > max0)
        {
            SWAP(max1,max0);
            SWAP(imax1,imax0);
        }
    }
}
}
/*-----

```

Subprogram write_gdr

Written by: Michael Caruso
Woods Hole Oceanographic Institution

Purpose: This subprogram writes the selected GDR to
standard output.

```

-----*/
write_gdr(j, prog)
    int j;
    char *prog;
{
    if (fwrite((char *)&frs[j], 1, REC_LEN, stdout) != REC_LEN)
    {
        geo_error(3,prog);
        exit(3);
    }
}
}

```

Program g_spline.c

/*

@(#)g_spline.c 1.3 12/15/89

Program g_spline.c

Written by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Modifications:

12-15-89 MC Changed call to geo_cyc_orb so that time is
passed and not a GDR.

Purpose:

This program will spline all geosat GDR data except the
10 per second heights againsts the latitude value.

Method:

1. Break data into continuous segments
2. Fit each segment with a spline
3. Spline each data value.
4. Write out all data between min and max

Usage:

The GEOSAT GDR is read from standard input.

cat c000.a002 | g_spline dir min max deltax timestep> c000.a002s

will spline the records from the GDR in c000.a002 between min
and max latitude if dir is 1 and between min and max longitudes
if dir is 2.

Input:

| | |
|----------|---|
| Stdin | Clean GEOSAT GDRs |
| dir | Determines boundaries of spline: |
| | 1 - Use latitude |
| | 2 - Use longitude |
| min | Minimum lat or lon. |
| max | Maximum lat or lon. |
| deltmax | Maximum gap in seconds for a contiguous segment. |
| timestep | Interval between spline points. |

Output:

Stdout: Splined GEOSAT GDRs. Values in gaps
 between valid segments are set to all
 zeros.

Subroutines Required:

geo_cyc_orb Returns the cycle number and orbit number
 for a given time.
natcubspline Computes a spline

References:

*/
include <math.h>
include <stdio.h>
include "geos.h"

#define NUMARGS 5
#define DIARG 1
#define MIARG 2
#define MAARG 3
#define DEARG 4
#define TIARG 5
#define MICRO 1e-6 /* Conv for utcm */
#define MAXPOINTS 2915 /* +/- degrees latitude */
/*
 Define some globals to share with fit subprograms...
*/

int ii, j, k;
int latstart, latstop;
struct frame frsin[MAXPOINTS]; /* frame MAXPOINTS/2 is defined at the equator */
struct frame frout[MAXPOINTS];
float timestep;
short int points=0;
float *x;
float *y2;
float *lat;
float *y;

float x0, minval, maxval;

/*
 Variables for orbit analysis.
*/
int orb, cyc;
double rs, rs3, cosinc, prec, rot, dthdt;
double time, theta, sinth, lat0, lon0, tmp;

short int seg_len[1000];

```

short int seg_beg[1000];

unsigned char ascorb;

main (argc,argv)
    int argc;
    char *argv[];
{

    int fit_time();
    int fit_data();

    double          time1, time2;  /* time variable used to determine gap */

    float deltax;

    short int i;

    short int dir;
    short int segments = 0;

    static char ScsId[] = "G(%)g_spline.c          1.4\t6/23/89";

    x = (float *)calloc(MAXPOINTS, sizeof(float));
    y2 = (float *)calloc(MAXPOINTS, sizeof(float));
    y = (float *)calloc(MAXPOINTS, sizeof(float));
    lat = (float *)calloc(MAXPOINTS, sizeof(float));

    if ((argc != NUMARGS+1) && (argc != 1))
    {
        fprintf(stderr,"Usage: %s [dir min max deltax timestep] < filein > fileout\n",
            argv[0]);
        exit(1);
    }
    if (argc == NUMARGS+1)
    {
        sscanf(argv[DIARG],"%hd", &dir);
        sscanf(argv[MIARG],"%f", &minval);
        sscanf(argv[MAARG],"%f", &maxval);
        sscanf(argv[DEARG],"%f", &deltax);
        sscanf(argv[TIARG],"%f", &timestep);
    }
    else
    {
        fprintf(stderr,"Usage: %s [dir min max deltax timestep] < filein > fileout\n",
            argv[0]);
        exit(1);
    }

    /*

```

```

    Read in all GDRs...
    */
    while (fread((char*)&frsin[points],1,REC_LEW,stdin)==REC_LEW) points++;
    points--;

    if (points <= 0)
    {
        fprintf(stderr,"%s: No points to spline\n\n",argv[0]);
        exit(0);
    }

/*
    Determine if orbit is ascending or descending...
*/
    if((frsin[0].lat < frsin[1].lat) && (frsin[1].lat < frsin[points].lat))
    {
        ascorb = TRUE;
    }
    else if((frsin[0].lat > frsin[1].lat) && (frsin[1].lat > frsin[points].lat))
    {
        ascorb = FALSE;
    }
    else
    {
        fprintf(stderr,"%s: Unable to determine if orbit is ascending or ");
        fprintf(stderr,"descending\n", argv[0]);
        exit(1);
    }

/*
    Set up for direction.  If dir != 1, then we
    find the latitude that corresponds to minlon
    and maxlon.
*/
    if (dir != 1)
    {
        lon_to_lat();
    }

/*
    Fill latitude array and find starting index...
*/
    for (i=0; i< MAXPOINTS; i++)
    {
        if (ascorb)
        {
            lat[i] = DEG*asin(sin((i-MAXPOINTS/2)*timestep*M2PI/PERIOD)*sin(INC));
            if (minval > lat[i]) latstart = i+1;
        }
        else
        {
            lat[i] = DEG*asin(sin(((MAXPOINTS/2)-i)*timestep*M2PI/PERIOD)*sin(INC));
            if (maxval < lat[i]) latstart = i+1;
        }
    }

```

```

    }

/*
  1. Break into data segments...
  */
seg_len[0] = 1;
seg_beg[0] = 0;
time2 = frsin[0].utc + frsin[0].utcm*MICRO;
for (i=0; i<points; i++)
{
    time1 = time2;
    time2 = frsin[i+1].utc + frsin[i+1].utcm*MICRO;

    if ((time2 - time1) <= deltax)
    {
        seg_len[segments]++;
    }
    else
    {
        segments++;
        seg_beg[segments] = i + 1;
        seg_len[segments] = 1;
    }
}

if (seg_len[0] == 0) exit(1);

/*
  2. Initialize data and fit a spline to each segment...
  */

for(i=latstart; i<MAXPOINTS; i++)
{
    frout[i].lat = (int)(lat[i]/MICRO);
    frout[i].lon = BAD;
    frout[i].m_h = BAD;
}

for (i=0; i<=segments; i++)
{
    fit_time(i);           /* initialize spline */
    fit_data(i,0);         /* lon */
    fit_data(i,1);         /* h */
    fit_data(i,2);         /* orb */
    fit_data(i,3);         /* s_h */
    fit_data(i,4);         /* geoid */
    fit_data(i,5);         /* swl */
    fit_data(i,6);         /* s_swl */
    fit_data(i,7);         /* s_nght */
    fit_data(i,8);         /* agc */
    fit_data(i,9);         /* s_agc */
    fit_data(i,10);        /* s_tide */
    fit_data(i,11);        /* o_tide */
}

```

```

        fit_data(i,12);          /* w_fnoc */
        fit_data(i,13);          /* w_smr */
        fit_data(i,14);          /* d_fnoc */
        fit_data(i,15);          /* iono */
        fit_data(i,16);          /* dh_swh */
        fit_data(i,17);          /* dh_fm */
        fit_data(i,18);          /* att */
    }

/*
   Write out points...
*/

for (k=latstart; k<j; k++)
{
    if (fwrite((char *)&front[k], 1, REC_LEN, stdout) != REC_LEN)
    {
        geo_error(3,argv[0]);
        exit(3);
    }
}

}

/*
-----
Subroutine fit_time
Written by:
    Michael Caruso
    Woods Hole Oceanographic Institution
    Woods Hole, MA

Purpose:
    This subprogram fits a spline to the time variable in a
    GEOSAT GDR.
-----
*/

int fit_time(i)
    int i;
{
    float yout;
    ii = 0;
    for (j=seg_beg[i]; j<seg_beg[i]+seg_len[i]; j++)
    {
        x[ii] = frsin[j].lat*MICRO;
        y[ii] = (float)(frsin[j].utc - frsin[seg_beg[i]].utc)
            + (float)frsin[j].utcm*MICRO;
        ii++;
    }
    x0 = x[0];

```



```

/*
  spline(x-1, y-1, ii, 1.e30, 1.e30, y2-1);
*/

  natcub spline(x, y, ii, x0, &yout, 0);

  j = latstart;
  while ((ascorb && (lat[j] < x0)) || (!ascorb && (lat[j] > x0)))
  {
    j++;
  }
  while ((lat[j] > minval) && (lat[j] < maxval))
  {
    if ((ascorb && (lat[j] > frsin[seg_beg[i]].lat*MICRO) &&
        (lat[j] < frsin[seg_beg[i]+seg_len[i]-1].lat*MICRO)) ||
        (!ascorb && (lat[j] < frsin[seg_beg[i]].lat*MICRO) &&
        (lat[j] > frsin[seg_beg[i]+seg_len[i]-1].lat*MICRO)))
    {
/*
      splint(x-1, y-1, y2-1, ii, lat[j], &yout);
*/
      natcub spline(x, y, ii, lat[j], &yout, 1);

      frout[j].utc = (int)yout + frsin[seg_beg[i]].utc;
      frout[j].utcm = (int)((yout - (int)yout)/MICRO);
    }
    else
    {
      frout[j].lat = (int)(lat[j]/MICRO);
      frout[j].utc = 0;
      frout[j].utcm = 0;
    }
    j++;
  }
  natcub spline(x, y, ii, lat[j], &yout, 2);

  return;
}
/*

```

Subroutine fit_data

Written by:

Michael Caruso

Woods Hole Oceanographic Institution

Woods Hole, MA

Purpose:

This subprogram fits a spline to the data segment specified.

```

/*

```

```

int fit_data(i, var)

```

```

    int i, var;
{

float yout;
int iout;
ii = 0;
for (j=seg_beg[i]; j<seg_beg[i]+seg_len[i]; j++)
{

    x[ii] = frsin[j].lat*MICRO;
    switch (var)
    {
        case 0:
            y[ii] = (float)frsin[j].lon;
            break;
        case 1:
            y[ii] = (float)frsin[j].m_h;
            break;
        case 2:
            y[ii] = (float)frsin[j].orb;
            break;
        case 3:
            y[ii] = (float)frsin[j].s_h;
            break;
        case 4:
            y[ii] = (float)frsin[j].geoid;
            break;
        case 5:
            y[ii] = (float)frsin[j].swh;
            break;
        case 6:
            y[ii] = (float)frsin[j].s_swh;
            break;
        case 7:
            y[ii] = (float)frsin[j].s_nght;
            break;
        case 8:
            y[ii] = (float)frsin[j].agc;
            break;
        case 9:
            y[ii] = (float)frsin[j].s_agc;
            break;
        case 10:
            y[ii] = (float)frsin[j].s_tide;
            break;
        case 11:
            y[ii] = (float)frsin[j].o_tide;
            break;
        case 12:
            y[ii] = (float)frsin[j].w_fnoc;
            break;
        case 13:
            y[ii] = (float)frsin[j].w_smmr;
            break;
    }
}

```

```

        case 14:
            y[ii] = (float)frsin[j].d_fnoc;
            break;
        case 15:
            y[ii] = (float)frsin[j].iono;
            break;
        case 16:
            y[ii] = (float)frsin[j].dh_swh;
            break;
        case 17:
            y[ii] = (float)frsin[j].dh_fm;
            break;
        case 18:
            y[ii] = (float)frsin[j].att;
            break;
        default:
            return(1);
    }

    ii++;
}
x0 = x[0];
/*
    spline(x-1, y-1, ii, 1.e30, 1.e30, y2-1);
*/
    natcubspline(x, y, ii, x0, &yout, 0);

    j = latstart;
    while ((ascorb && (lat[j] < x0)) || (!ascorb && (lat[j] > x0)))
    {
        j++;
    }
    while ((lat[j] > minval) && (lat[j] < maxval))
    {
        if ((ascorb && (lat[j] > frsin[seg_beg[i]].lat*MICRO) &&
            (lat[j] < frsin[seg_beg[i]+seg_len[i]-1].lat*MICRO)) ||
            (!ascorb && (lat[j] < frsin[seg_beg[i]].lat*MICRO) &&
            (lat[j] > frsin[seg_beg[i]+seg_len[i]-1].lat*MICRO)))
        {
            /*
                splint(x-1, y-1, y2-1, ii, lat[j], &yout);
            */
            natcubspline(x, y, ii, lat[j], &yout, 1);

            iyout = nint(yout);
            set_data(j, iyout, var);
        }
        else
        {
            set_data(j, BAD, var);
        }
        j++;
    }
    natcubspline(x, y, ii, lat[j], &yout, 2);

```

```

    return(0);
}

/*
-----
Subroutine set_data

Written by:
    Michael Carnuso
    Woods Hole Oceanographic Institution
    Woods Hole, MA

Purpose:
    This subroutine simply puts the data into the
    correct element.
-----
*/
int set_data(point, data, var)
    int point;
    int data;
    int var;
{
    switch (var)
    {
        case 0:
            frout[point].lon = data;
            break;
        case 1:
            frout[point].m_h = data;
            break;
        case 2:
            frout[point].orb = data;
            break;
        case 3:
            frout[point].s_h = data;
            break;
        case 4:
            frout[point].geoid = data;
            break;
        case 5:
            frout[point].swh = data;
            break;
        case 6:
            frout[point].s_swh = data;
            break;
        case 7:
            frout[point].s_nght = data;
            break;
        case 8:
            frout[point].agc = data;
            break;
        case 9:
            frout[point].s_agc = data;
    }
}

```

```

        break;
    case 10:
        frout[point].s_tide = data;
        break;
    case 11:
        frout[point].o_tide = data;
        break;
    case 12:
        frout[point].w_fnoc = data;
        break;
    case 13:
        frout[point].w_smr = data;
        break;
    case 14:
        frout[point].d_fnoc = data;
        break;
    case 15:
        frout[point].iono = data;
        break;
    case 16:
        frout[point].dh_swh = data;
        break;
    case 17:
        frout[point].dh_fm = data;
        break;
    case 18:
        frout[point].att = data;
        break;
    default:
        return(1);
    }
}

```

/*

Subroutine lon_to_lat

Written by:

Michael Caruso

Woods Hole Oceanographic Institution

Woods Hole, MA

Purpose:

This subroutine converts the minval and
maxval when given in longitude to latitude.

*/

int

lon_to_lat()

{

int i;

float tmpval;

double tmptime;

```

/* Determine orbit number */
tmptime = frsin[0].utc + frsin[0].utcm*MICRO;
geo_cyc_orb(tmptime, &cyc, &orb);

rs = RE + frsin[0].orb;
rs3 = rs*rs*rs;
cosinc = cos(INCL);
prec = -1.5*J2*sqrt(GM/rs)*RE*RE*cosinc/rs3;
rot = prec - (M_PI_2/SD);
dthdt = M2PI/PERIOD;

/*
  Loop until we find min_lat and
  max_lat.
*/

lon0 = frsin[0].lon*1.0e-6*RAD;
time = 0.0;

if (ascorb)
{
  i = 0;
  while (lon0 > maxval*RAD)
  {
    i++;
    lon0 = frsin[i].lon*1.0e-6*RAD;
  }

  while (lon0 < maxval*RAD)
  {
    time += timestep;
    theta = dthdt*time;
    sinth = sin(theta);
    lat0 = (frsin[i].lat*1.0e-6)*RAD + asin(sin(INCL)*sin(theta));
    tmp = cosinc*sinth/cos(lat0);
    tmp = (tmp>1.0) ? 1.0 : tmp;
    tmp = (tmp<-1.0) ? -1.0 : tmp;
    lon0 = (asin(tmp) + rot*time) + frsin[i].lon*1.0e-6*RAD;
  }

  lon0 = frsin[points].lon*1.0e-6*RAD;
  tmpval = lat0*DEG;
  time = 0.0;
  i = points;
  while (lon0 < minval*RAD)
  {
    i--;
    lon0 = frsin[i].lon*1.0e-6*RAD;
  }
  while (lon0 > minval*RAD)
  {

```

```

        time += timestep;
        theta = dthdt*time;
        sinh = sin(theta);
        lat0 = (frsin[i].lat*1.0e-6)*RAD + asin(sin(INCL)*sin(theta));
        tmp = cosinc*sinh/cos(lat0);
        tmp = (tmp>1.0) ? 1.0 : tmp;
        tmp = (tmp<-1.0) ? -1.0 : tmp;
        lon0 = (asin(tmp) + rot*time) + frsin[i].lon*1.0e-6*RAD;
    }
    minval = tmpval;
    maxval = lat0*DEG;
}
else
{
    lon0 = frsin[0].lon*1.0e-6*RAD;
    time = 0.0;
    i = 0;
    while (lon0 > maxval*RAD)
    {
        i++;
        lon0 = frsin[i].lon*1.0e-6*RAD;
    }

    while (lon0 < maxval*RAD)
    {
        time -= timestep;
        theta = dthdt*time;
        sinh = sin(theta);
        lat0 = (frsin[i].lat*1.0e-6)*RAD + asin(sin(INCL)*sin(theta));
        tmp = cosinc*sinh/cos(lat0);

        tmp = (tmp>1.0) ? 1.0 : tmp;
        tmp = (tmp<-1.0) ? -1.0 : tmp;
        lon0 = (asin(tmp) + rot*time) + frsin[i].lon*1.0e-6*RAD;
    }

    maxval = lat0*DEG;
    lon0 = frsin[points].lon*1.0e-6*RAD;
    time = 0.0;
    i = points;
    while (lon0 < minval*RAD)
    {
        i--;
        lon0 = frsin[i].lon*1.0e-6*RAD;
    }
    while (lon0 > minval*RAD)
    {
        time += timestep;
        theta = dthdt*time;
        sinh = sin(theta);
        lat0 = (frsin[i].lat*1.0e-6)*RAD + asin(sin(INCL)*sin(theta));

        tmp = cosinc*sinh/cos(lat0);

```

```

        tmp = (tmp>1.0) ? 1.0 : tmp;
        tmp = (tmp<-1.0) ? -1.0 : tmp;
        lon0 = (asin(tmp) + rot*time) + frsin[i].lon*1.0e-6*RAD;
    }
    minval = lat0*DEG;
}
}

```


Program g_uncompress.c

/*

@(#)g_uncompress.c 1.2 6/14/90

Written by:

Pierre Flament
Oceanography Department
University of Hawaii
Honolulu, HI

Modifications:

Mike Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Purpose:

Uncompress compressed geosat data from 18 bytes/frame to
standard NOAA data frame; leave 0 for items lost
in compression.

| item | parameter | units | range | type |
|------|-----------------------|---------|-------------|-------------------|
| 1 | TIME since start a000 | ms | 0 to 1.4/e9 | long int (4) |
| 2 | HEIGHT | cm | 0 to 32766 | short int (2) |
| 3 | CYCLE number | | 0... | char (1) |
| 4 | LATITUDE+90 deg. | 10-4deg | 0 to 18e5 | unsigned int (3) |
| 5 | LONGITUDE | 10-4deg | 0 to 36e5 | unsigned int (3) |
| 6 | SIGMA HEIGHT | cm | 0 to 255 | unsigned char (1) |
| 7 | SWR | 5cm | 0 to 255 | unsigned char (1) |
| 8 | So | .1db | 0 to 255 | unsigned char (1) |
| 9 | FLAGS | | | char (1) |
| 10 | OCEAN TIDE | cm | -128 to 128 | char (1) |

Method:

Usage:

g_uncompress < file.18b > file.gdr

Input:

18-byte data record

Output:

Pseudo Geosat GDR

```
*/
# include <stdio.h>

# define PERIOD 6037.551518571
# define START_TIME 58406188.43 /* equator xing orbit c000.a000 */
# define BAD 32767

/* this is the standard geosat frame */

struct in_frame {
    long int utc,utcm,lat,lon,orb;
    short int m_h,s_h,geoid,h[10],swh,s_swh,s_nght,agc,s_agc;
    char fl[2];
    short int h_off,s_tide,o_tide,w_fnoc,w_smmr,d_fnoc,iono,dh_swh,dh_fm,att;
};

struct in_frame in;

/* this is the compressed frame. Order is important since compiler
forces short int on even word boundaries */

struct out_frame {
    long int utc;
    short int m_h;
    char cycle_n;
    char lat[3],lon[3];
    unsigned char s_h,swh,s_nght;
    char fl;
    char o_tide;
};

struct out_frame out;

char junk[4];

double time,cycle=244*PERIOD;

int i,j;

main()

{
while(fread((char*)&out,1,18,stdin)==18)
    {
        time=out.utc/1000.+START_TIME+out.cycle_n*cycle;
        /* implicit cast to long int */
        in.utc=(long int)time;
        in.utcm=(long int)((time-(long int)time)*1e6);
    }
}
```

```

junk[1]=out.lat[0];
junk[2]=out.lat[1];
junk[3]=out.lat[2];

in.lat=(*(long int*)&junk[0]-900000)*100;

junk[1]=out.lon[0];
junk[2]=out.lon[1];
junk[3]=out.lon[2];

in.lon=(*(long int*)&junk[0])*100;

in.m_h=out.m_h;

in.s_h=(out.s_h==255?BAD:out.s_h);
in.swh=(out.swh==255?BAD:out.swh*5);
in.s_nght=(out.s_nght==255?BAD:out.s_nght*10);
in.fl[1]=out.fl;
in.s_h=(out.s_h==255?BAD:out.s_h);
in.o_tide=(out.o_tide==127?BAD:out.o_tide*10);
fwrite((char*)&in,1,78,stdout);
}

```

```

}

```

Program g_which.c

/*

@(#)g_which.c 1.4 11/14/89

Program g_which.c

Written by:

Michael Caruso

Woods Hole Oceanographic Institution

Woods Hole, MA

Modifications:

Original concept by P. Flament

Woods Hole Oceanographic Institution

Woods Hole, MA

Purpose:

Reads minimum latitude and longitude, maximum latitude and longitude and returns the orbit numbers within that box.

Usage:

The program reads the minimum and maximum latitudes and longitudes from the command line. If only two arguments are given, they are taken to be a lat/lon point and the nearest ascending and descending tracks are found.

g_which 30 45 280 300

or

g_which 30 280

Input:

None

Output:

Orbit numbers suitable for use in a chain of pipes:

cat c0/c000.'g_which 30 45 380 300' | g_ext 1 L

Subroutines required:

geo_which

returns an array of 1's and 0's for each cycle within the desired box.

References:

Bugs:

Assumes input data contains complete orbits.

*/

```
#include <stdio.h>
#include <sys/file.h>
#include <math.h>
#include "geos.h"
```

```
#define NUMARG      4
#define NUMARG2     2
#define MMLTARG     1
#define MXLTARG     2
#define MMLWARG     3
#define MXLWARG     4
#define MMLWARG2    2
```

```
char *cm=""; /* single , for print statement */
```

```
main(argc, argv)
    int argc;
    char *argv[];
{
```

```
    unsigned char a[ORB_PER_CYC],
                  d[ORB_PER_CYC]; /* arrays of orbits within box */
```

```
    int i; /* Counter */
```

```
    double min_lat,
            max_lat,
            min_lon,
            max_lon; /* input lon-lat box */
```

```
    /*
    Read command line arguments.
    */
```

```
    if (argc == NUMARG + 1)
    {
        sscanf(argv[MMLTARG], "%lf", &min_lat);
        sscanf(argv[MXLTARG], "%lf", &max_lat);
        sscanf(argv[MMLWARG], "%lf", &min_lon);
        sscanf(argv[MXLWARG], "%lf", &max_lon);
```

```

    }
else if (argc == NUMARG2 +1)
{
    sscanf(argv[MNLTARG], "%lf", &min_lat);
    sscanf(argv[MNLTARG2], "%lf", &min_lon);
    max_lat = min_lat;
    max_lon = min_lon;
}
else
{
    fprintf(stderr, "Usage: %s min_lat max_lat min_lon max_lon\n", argv[0]);
    fprintf(stderr, " Or\n");
    fprintf(stderr, "      %s lat lon\n", argv[0]);
    exit(1);
}

/* determine orbits to remove. */

geo_which(min_lat, max_lat, min_lon, max_lon, a, d);

fprintf(stdout, "{");
for (i=0; i<ORB_PER_CYC; i++)
{
    if(a[i]) {fprintf(stdout, "%sa%03d", cm, i); cm=",";}
    if(d[i]) {fprintf(stdout, "%sd%03d", cm, i); cm=",";}
}
fprintf(stdout, "}");
}

```

Program s_ext.c

/*

@(#)s_ext.c 1.1 12/14/89

Program s_ext.c

Written by:

Mimi Baker
Pierre Flament
Oceanography Department
University of Hawaii
Honolulu, HI

5 October 1989

Modifications:

14 October 1989 MJC changed include ssmi.h to
geos.h for future compatibility.

Purpose:

To extract user specified data from an SSMI record

Method:

Reads raw SSMI data from standard input and applies
corrections and conversions. Reads user desired output variables
from command line arguments. Writes output on standard output in
ASCII format.

Usage:

The SSMI data are read from standard input and output variables are
read from the command line.

cat s000.a002 | s_ext t l L > file.asc

will extract the time, latitude and longitude for each point
in the file s000.a002.

Input:

Stdin Raw SSMI data, except for the times which are in
 GEOSAT time.

Output

Stdout Extracted ASCII format

Subroutines required:

None

References:

None

*/

```
# include <math.h>
# include <stdio.h>
# include <string.h>
# include "geos.h"
```

```
# define MXP      9          /* max number of parameters */
# define NCH      4          /* number of SSMI channels:
                               0 and 3 are long int
                               1 and 2 are short int */
```

```
# define PRINT(X) printf(form[col[i]],X)
```

```
char* val[NCH+5]={"t","l","L","fl","ws","vp","cl","rn","cws"};
```

```
/* in which
```

| | | |
|-----|-----------------|--|
| t | (seconds) | time since START_TIME |
| l | (degrees) | latitude |
| L | (degrees) | east longitude |
| fl | (-) | flag indicating data characteristics =0, over ocean =1, no orbit altitude information =2, over land =3, over sea ice |
| ws | (meters/second) | wind speed (NOTE: if = BAD, no wind due to rain) |
| vp | (kg/m*m) | columnar water vapor (NOTE: if = BAD, no water vapor due to rain) |
| cl | (kg/m*m) | columnar cloud water |
| rn | (mm/hr) | rain rate |
| cws | (meters) | SSMI correction for water vapor |

*/

```
/* formats for printing output fields          */
```

```
char* form[NCH+5]={"%10.11f\t","%6.21f\t","%6.21f\t","%d\t",
                   "%6.21f\t","%6.21f\t","%8.41f\t","%7.31f\t",
                   "%8.41f\t"};
```

```
int i,j,col[MXP];
```



```

double ws(),vp(),cl(),rn(),cws();
double lat,lon;

main (argc,argv)
int argc;
char *argv[];

{
    for(j=0;j<NXP;j++)
        col[j] = -1;

    argc--;
    argv++;

    if (argc==0)
    {
        fprintf(stderr,"sex: argument error\n");
        exit(1);
    }

    /* find which channels should be processed
       i: argument/column index
       j: channel number
       col[i]: channel number corresponding to column i
       */

    for (i=0;i<argc;i++)
        for (j=0;j<NCH+6;j++)
            if(!strcmp(argv[i],val[j])) {col[i]=j;break;}

    while (fread((char*)&frssmi,1,12,stdin)==12)
    {
        lat = frssmi.lat*1.0e-02;
        lon = frssmi.lon*1.0e-02 + 180.;

        if (frssmi.flag!=0) continue;

        for (i=0;i<argc;i++)
            if (col[i]==0)
                PRINT(frssmi.utc-START_TIME);
            else if (col[i]==1)
                PRINT(lat);
            else if (col[i]==2)
                PRINT(lon);
            else if (col[i]==3)
                PRINT((int)frssmi.flag);
            else if (col[i]==4)
                PRINT(ws());
            else if (col[i]==5)
                PRINT(vp());
            else if (col[i]==6)

```

```

        PRINT(cl());
    else if (col[i]==7)
        PRINT(rn());
    else if (col[i]==8)
        PRINT(cws());
    printf("\n");
}
}

double ws()
/* computes wind speed */

{
    double wind;

    wind = 0.2*(frsml.win - 30.);
    if (wind == 45.0) wind = BAD;
    return(wind);
}

double vp()
/* computes water vapor */

{
    double vapor;

    vapor = 0.04*(frsml.vap - 5.0);
    if (fabs(vapor - 10.) < 1.e-3 )
        vapor = BAD;
    else
        vapor = vapor*10.;
    return(vapor);
}

double cl()
/* computes cloud water */

{
    double cloud;

    cloud = 0.5*(frsml.cld -32)*1.0e-02;
    return(cloud);
}

double rn()
/* computes rain rate */

{
    double rain;

    rain = 0.193*cl()*1.0e02 -0.48;
    if (rain < 0.0)
        rain = 0.0;
    return(rain);
}

```

}

```
double cws()  
/* computes GEOSAT correction for water vapor
```

References:

P.A. Phoebus and J.D. Hawkins, 'The impact of water vapor attenuation on the interpretation of altimeter-derived ocean topography in the Northeast Pacific', submitted to JGR, special GEOSAT issue, June 1989

B.D. Tapley and J.B. Lundberg, 'The SEASAT altimeter wet tropospheric range correction', JGR 87 pp. 3213-3220, 1982

*/

```
{  
    double wettrop;  
  
    if (vp() == BAD)  
        wettrop = BAD;  
    else  
        wettrop = -0.00636*vp();  
    return(wettrop);  
}
```

Program s_region.c

/*

@(#)s_region.c 1.2 12/14/89

Program s_region.c

Written by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Modifications:

Mimi Baker
Oceanography Department
University of Hawaii
Honolulu, HI

modified g_region to s_region to process SSMI data
4 October 1989

MC 14 Oct 1989, changed include file ssmi.h to geos.h
for future compatibility.

MB 28 Nov 1989, changed calls to geo_cyc_orb to reflect
changes in geo_cyc_orb.

Purpose:

Decodes SSMI data and separates raw data into separate orbits. Each orbit is defined as beginning at the northernmost point of a track. Each orbit is further separated into an ascending section and a descending section. Orbits are then written out to separate files of the form:

ssmm.annn or smmn.nnnd

where

| | |
|------|-------------------------------------|
| ssmm | is the cycle number, |
| nnn | is the orbit number for that cycle, |
| a | signifies ascending portion, |
| d | signifies descending portion. |

The data is written out in the same form as it was read in. This is consecutive records of 12 bytes each.

Usage:

The program reads the minimum and maximum latitudes and longitudes from the command line and reads the data from standard input. To use

the program to extract data from the tape (/dev/rmt8, 6250bpi, input block size 14400) issued by Wentz, from 10W to 30W and 280E to 300E:

```
dd if=/dev/rmt8 ibs=14400 | s_region 1 10 30 280 300
```

The first number on the argument line specifies whether the box should be bounded by a latitude line(1) or a longitude line(2). Note that longitudes are all east of Greenwich and if the box selected spans 360E, add 360 degrees to right edge of box, ie 350 365.

Input:

Stdin Raw SSMI data

Output:

s???.???? SSMI data within region separated in ascending and descending orbits, with times consistent with GEOSAT times.

Subroutines required:

geo_which returns an array of 1's and 0's for each cycle within the desired box.
geo_error prints error messages to standard error.
geo_cyc_orb return orbit and cycle number

References:

Bugs:

Assumes input data contains complete orbits.

*/

```
#include <stdio.h>
#include <sys/file.h>
#include <math.h>
#include "geos.h"

#define NUMARG 5
#define DIRARG 1
#define MMLTARG 2
#define MMLTARG 3
#define MMLWARG 4
#define MMLWARG 5
#define SEC_YR2 2.*365.*24.*3600. /* 2 times seconds per year */
```

```
main(argc, argv)
    int argc;
    char *argv[];
```

```

{

struct frames frssmi2;

unsigned char a[ORB_PER_CYC],
             d[ORB_PER_CYC]; /* arrays of orbits within box */

char         str[80];        /* string for output file name */

short int    dir;            /* Direction of lat/lon boundary */
short int    orbit_num_tot; /* the total number of orbits */
int          cycle_num;      /* the number of cycles since */
int          orbit_num;      /* orbit number within cycle 0-244 */
short int    isopen = FALSE; /* check to see if file is already open */
short int    asc;            /* flag for ascending or descending */

long int     llcmp,
             llmin, llmax; /* lat/lon boundary */
long int     lslope1,
             lslope2;      /* "Slope" of orbit */

double       min_lat,
             max_lat,
             min_lon,
             max_lon;      /* input lon-lat box */
double       time;         /* time variable */

FILE *fdout;               /* output file descriptor */

/*
Read command line arguments.
*/

if (argc == NUMARG + 1)
{
    sscanf(argv[DIRARG], "%hd", &dir);
    sscanf(argv[MNLTARG], "%lf", &min_lat);
    sscanf(argv[MXLTARG], "%lf", &max_lat);
    sscanf(argv[MNLTARG], "%lf", &min_lon);
    sscanf(argv[MXLTARG], "%lf", &max_lon);
}
else
{
    fprintf(stderr, "Usage: %s dir min_lat max_lat min_lon max_lon\n", argv[0]);
    exit(1);
}

/* determine orbits to remove. */

geo_which(min_lat, max_lat, min_lon, max_lon, a, d);

```

```

/* Set llmin, llmax... */

if (dir == 1)
{
    llmin = (int) (min_lat*1.0e02);
    llmax = (int) (max_lat*1.0e02);
}
else
{
    llmin = (int) ((min_lon - 18000)*1.0e02);
    llmax = (int) ((max_lon - 18000)*1.0e02);
}

/* read initial lat and long coordinates */

if(fread((char *)&frssmi,1,SSMIREC,stdin) != SSMIREC)
{
    geo_error(2, argv[0]);
    exit(2);
}
frssmi.utc = frssmi.utc + SEC_YR2;

if(fread((char *)&frssmi2,1,SSMIREC,stdin) != SSMIREC)
{
    geo_error(2, argv[0]);
    exit(2);
}
frssmi2.utc = frssmi2.utc + SEC_YR2;

/* Determine name of first orbit */

time = frssmi.utc;
lslope1 = frssmi2.lat - frssmi.lat;
/*
orbit_num_tot = (int)floor((time-TIME_ZERO)/PERIOD);
cycle_num      = orbit_num_tot / ORB_PER_CYC;
orbit_num      = orbit_num_tot % ORB_PER_CYC;
*/

geo_cyc_orb(time, &cycle_num, &orbit_num);

/*
Check to see if first orbit is ascending or
descending...
*/

if ( lslope1 > 0 )
{
    sprintf(str,"%3d.a%.3d",cycle_num,orbit_num);
    asc = TRUE;
}
else if ( lslope1 < 0)

```

```

    {
        sprintf(str,"%3d.%3d",cycle_num,orbit_num);
        asc = FALSE;
    }
else
    {
        if (frssmi.lat < 0)
        {
            sprintf(str,"%3d.a%3d",cycle_num,orbit_num);
            asc=TRUE;
        }
        else
        {
            sprintf(str,"%3d.d%3d",cycle_num,orbit_num);
            asc=FALSE;
        }
    }

/* Check to see if point is an orbit we want and greater
   than the minimum latitude and smaller than the
   maximum latitude. If so, write to the output file. If
   the output file is not open, open it and mark it as
   being open.      */

llcmp = (dir == 1) ? frssmi.lat : frssmi.lon;

if(((asc && a[orbit_num]) || (!asc && d[orbit_num])) && (llcmp > llmin)
    && (llcmp < llmax))
{
    if (isopen == 0)
    {
        fdout = fopen(str,"a");
        isopen = 1;
    }
    if(fwrite((char *)&frssmi,1,SSMIREC,fdout) != SSMIREC)
    {
        geo_error(3, argv[0]);
        exit(3);
    }
}

/*
Check second point...
*/

llcmp = (dir == 1) ? frssmi2.lat : frssmi2.lon;

if(((asc && a[orbit_num]) || (!asc && d[orbit_num])) && (llcmp > llmin)
    && (llcmp < llmax))
{
    if (isopen == 0)
    {
        fdout = fopen(str,"a");
        isopen = 1;
    }
}

```



```

    }
    if(fwrite((char *)&frssmi2,1,SSMIREC,fdout) != SSMIREC)
    {
        geo_error(3, argv[0]);
        exit(3);
    }
}

/* Read in rest of geosat data. We keep three points active
to monitor when an orbit changes from ascending to descending.
This was done because of the incomplete data at high latitudes.
*/

frssmi = frssmi2;

while(fread((char *)&frssmi2,1,SSMIREC,stdin) == SSMIREC)
{
    frssmi2.utc = frssmi2.utc + SEC_YR2;
    lslope2 = frssmi2.lat - frssmi.lat;

    if ((lslope1 > 0 && lslope2 <= 0) || (lslope1 < 0 && lslope2 >= 0))
    {
        /* Determine name of next orbit */

        time = frssmi2.utc;

/*
        orbit_num_tot = (int)floor((time-TIME_ZERO)/PERIOD);
        cycle_num      = orbit_num_tot / ORB_PER_CYC;
        orbit_num      = orbit_num_tot % ORB_PER_CYC;
*/

        geo_cyc_orb(time, &cycle_num, &orbit_num);

        if ( lslope2 > 0 )
        {
            sprintf(str,"s%.3d.a%.3d",cycle_num,orbit_num);
            asc=TRUE;
        }
        else if ( lslope2 < 0 )
        {
            sprintf(str,"s%.3d.d%.3d",cycle_num,orbit_num);
            asc=FALSE;
        }
        else
        {
            if (frssmi2.lat < 0 )
            {
                sprintf(str,"s%.3d.a%.3d",cycle_num,orbit_num);
                asc=TRUE;
            }
        }
    }
}

```

```

        else
        {
            sprintf(str,"%%.3d.d%.3d",cycle_num,orbit_num);
            asc=FALSE;
        }
    }

    fclose(fdout);          /* Close previous file */
    isopen = 0;
}

llcmp = (dir == 1) ? frssmi2.lat : frssmi2.lon;

if(((asc && a[orbit_num]) || (!asc && d[orbit_num])) && (llcmp > llmin)
    && (llcmp < llmax))
{
    if (isopen == 0)
    {
        fdout = fopen(str,"a");
        isopen = 1;
    }
    if(fwrite((char *)&frssmi2,1,SSMIREC,fdout) != SSMIREC)
    {
        geo_error(3, argv[0]);
        exit(3);
    }
}

frssmi = frssmi2;
lslope1 = lslope2;
}
}

```

Subroutine geo_cyc_orb.c

```
/*
  @(#)geo_cyc_orb.c      1.3 6/14/90

  Written by:
  -----
  Michael Caruso
  Woods Hole Oceanographic Institution.
  Woods Hole, MA

  Modified by:
  -----
  Mimi Baker
  Oceanography Department
  University of Hawaii
  Honolulu, HI

  28 November 1989, to make subroutine frame independent
  and a function of time only.

  Purpose:
  -----
  This subroutine calculates the orbit number of
  a given GEOSAT GDR or SSMI data.

  Usage:
  -----
  geo_cyc_orb(time, cyc, orb)
             double time      time of record
             int *cyc;        the cycle number
             int *orb;        the orbit number

  Returns:
  -----
  -1          on error.

  Reference:
  None.

*/

#include "geos.h"
#include <math.h>

int geo_cyc_orb(time, cyc, orb)
    double time;
    int *cyc, *orb;
{
    double orbit;
```

```

int orbit_num_tot;

if ((time - TIME_ZERO) < 0 )
    return(-1);

orbit = (time-TIME_ZERO)/PERIOD;
orbit_num_tot = (int)floor(orbit);

if((orbit - (int)orbit) > 0.99)
    orbit_num_tot += 1;

*cyc    = orbit_num_tot / ORB_PER_CYC;
*orb    = orbit_num_tot % ORB_PER_CYC;

return;
}

```

Subroutine geo_error.c

```
/*
@(#)geo_error.c      1.2 6/14/90

Written by:
-----
Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA
October 1988

Purpose:
-----
This program prints an error message to standard error
along with the name of the program that generated the
error.

Method:
-----

Usage:
-----
    geo_err(num, progame)
        int      num          Error number to print.
        char     *progame     Program generating error.

Input:
-----
    num          Error number to print.
    *progame     Pointer to name of program generating error.

Output:
-----
    Error message to standard error.

Returns:
-----
    None.

Subroutines Required:
-----
    None.

*/

#include <stdio.h>
#define NUMMSG      4
```

```

/*
    define array of error messages...
*/

char *mesg[] = {"Unrecoverable error\n",
                "c???.[ad]???\n",
                "Error reading file\n",
                "Error writing file\n"};

geo_error(num, prog)
    long num;
    char *prog;
{
    if (num < NUMMSG)
        fprintf(stderr,"%s: %s", prog, mesg[num]);
    else
        fprintf(stderr,"%s: %s", prog, mesg[0]);
}

```

Subroutine geo_mask.c

```
/*
  @(#)geo_mask.c      1.3 6/14/90

  Written by:
  -----
  Pierre Flament
  Oceanography Department
  University of Hawaii
  Honolulu, HI

  Modifications:
  -----
  Mike Caruso
  Woods Hole Oceanographic Institution
  Woods Hole, MA

  Purpose:
  -----
  Reads in environment variable GMASK if available
  and converts to integers. Any character other
  than a 0 or a 1 is ignored.

  Method:
  -----
  Checks to see if the user has set an environment
  variable GMASK. If so, the program returns it.

  Input:
  -----
  None

  Output:
  -----
  msk
  valid

  Returns:
  -----
  msk      an integer with bits set to correspond
           to GMASK values of 1
  valid    an integer with bits set to correspond
           to GMASK values of 0 and 1

*/
#define NULL 0
geo_mask(msk,valid)

short int *msk,*valid;
```

```

{
    char * getenv();

    char* st="1-----0-----00"; /* default mask; - can be any char */
    int i;

    if (getenv("GMASK")!=NULL) st=getenv("GMASK");

    for (i=0 ; *(st+i)!='\0' && i<16 ; i++)
    {
        if (*(st+i)=='1') *valid += 1<<i;
        if (*(st+i)=='1' || *(st+i)=='0') *mask += 1<<i;
    }
.}

```


Subroutine geo_which.c

/*

@(#)geo_which.c 1.3 6/14/90

Written by:

Pierre Flament
Woods Hole Oceanographic Institution
Woods Hole, MA

Modified by:

Michael Caruso
Woods Hole Oceanographic Institution
Woods Hole, MA

Purpose:

This procedure determines which orbit numbers cross a given area.

Method:

Find the times when ascending and descending parts of orbit 000 cross min_lat and max_lat. Find the corresponding longitudes for that orbit. Then repeatedly shift the orbit by INCR, the ground spacing between successive orbits, and flag those that cross the box.

Only a first order sinusoidal approximation of the orbit ground path is used.

Usage:

geo_which(min_lat, max_lat, min_lon, max_lon, a, d)
 int min_lat, max_lat
 int min_lon, max_lon
 unsigned char *a, *d

Input:

min_lat minimum latitude of box.
max_lat maximum latitude of box.
min_lon minimum eastward longitude of box.
max_lon maximum eastward longitude of box.

Output:

*a array of 244 elements. Array has
 1 in location i if ascending orbit

```

        i crosses box, 0 otherwise.
    *d      Same as *a, except for descending
           orbits.

Returns:
-----
    None.

Subroutines Required:
-----
    double    fold(x)    folds angle x, in radians, to the range 0-2*M_PI.

Reference:
    None.

*/

#include "geos.h"
#include <stdio.h>
#include <math.h>

# define SWAP(X1,X2) {x=X1;X1=X2;X2=x;}

# define NODE    (START_LOM*RAD)          /* the longitude Xing of c000.a000 */
# define OM      (2*M_PI/PERIOD)           /* orbital omega */
# define DELT    (2*M_PI/244.)            /* the increment between adjacent orbits */
*/
# define INCR    (2*M_PI*17./244.)        /* the increment between successive orbits */
*/
# define REP     (OM*17./244.)            /* 1/17 of the repeat cycle */
# define SINCL   (sin(INCL))              /* the sin of inclination */
# define COSCL   (cos(INCL))              /* the cos of inclination */
# define EPSLAT  (5.e-2)                  /* tolerance at +- INCL */

double
    min_time_a, /* time orbit a000 crosses min_lat */
    min_time_d, /* time orbit d000 crosses min_lat */
    max_time_a, /* time orbit a000 crosses max_lat */
    max_time_d, /* time orbit d000 crosses max_lat */
    min_lon_a, /* longitude where asc orbit crosses min_lat */
    min_lon_d, /* longitude where dec orbit crosses min_lat */
    max_lon_a, /* longitude where asc orbit crosses max_lat */
    max_lon_d, /* longitude where dec orbit crosses max_lat */
    del_lon, /* longitude width of the box */
    x; /* dummy variable */

int
    i, s;

geo_which(min_lat, max_lat, min_lon, max_lon, a, d)
    double min_lat, max_lat, min_lon, max_lon;
    unsigned char *a, *d;

```

```

{

double fold();

/* check order of min,max_lat, SWAP if necessary, convert to RAD */

if (min_lat > max_lat) SWAP(min_lat,max_lat);
min_lat ** RAD;
max_lat ** RAD;

/* check to see if min,max_lat exceed satellite inclination.*/

min_lat = (min_lat>M_PI-INCL?M_PI-INCL-EPSSLAT:min_lat);
min_lat = (min_lat<INCL-M_PI?INCL-M_PI+EPSSLAT:min_lat);

max_lat = (max_lat>M_PI-INCL?M_PI-INCL-EPSSLAT:max_lat);
max_lat = (max_lat<INCL-M_PI?INCL-M_PI+EPSSLAT:max_lat);

/* convert lon to RAD and check to see if the calling program has
   selected an individual point */

min_lon ** RAD;
max_lon ** RAD;

if (min_lon == max_lon )
{
    min_lon = min_lon-DELT/2;
    max_lon = max_lon+DELT/2;
}

/* min,max_lon are always given in the right order. Fold them
   so that they are always in the range 0 to 4*M_PI and
   max_lon>min_lon */

while (min_lon > max_lon) max_lon += 2*M_PI;
del_lon = max_lon - min_lon;
min_lon = fold(min_lon);
del_lon = fold(del_lon);
max_lon = min_lon + del_lon;

/* find times at which orbit a000 crosses min_lat and max_lat;
   the origin of time is at the ascending node */

min_time_a = asin(sin(min_lat)/SINCL)/OM;
max_time_a = asin(sin(max_lat)/SINCL)/OM;

/* find times at which orbit d000 crosses min_lat and max_lat;
   d000 is BEFORE a000; the origin of time is at the ascending node */

min_time_d = -PERIOD/2 - min_time_a;
max_time_d = -PERIOD/2 - max_time_a;

/* find corresponding longitudes; here min_lon_? correspond to min_time_?,
   and do not necessarily mean a minimum longitude */

```

```

min_lon_a = fold(WODE+atan2(COSCL*sin(OM*min_time_a),cos(OM*min_time_a))-
min_time_a*REP);
min_lon_d = fold(WODE+atan2(COSCL*sin(OM*min_time_d),cos(OM*min_time_d))-
min_time_d*REP);
max_lon_a = fold(WODE+atan2(COSCL*sin(OM*max_time_a),cos(OM*max_time_a))-
max_time_a*REP);
max_lon_d = fold(WODE+atan2(COSCL*sin(OM*max_time_d),cos(OM*max_time_d))-
max_time_d*REP);

/* check if orbit crosses the given box, then shift the orbit by INCR.
A given orbit crosses the box if the top right and bottom left
corners fall on opposite sides of an ascending orbit, or if the
top left and bottom right corners fall on the opposite sides of
a descending orbit. This can be expressed by the conditions

(min_lon-min_lon_a)*(max_lon-max_lon_a)<=0

(max_lon-min_lon_d)*(min_lon-max_lon_d)<=0

given the definition of min_lon_a, etc...
*/

for(i=0;i<244;i++)
{

/* special care must be taken when the orbit spans 360; in that
case, max_lon_d and min_lon_a were folded too much and 2*M_PI
must first be added to them */

if(min_lon_a<max_lon_a) min_lon_a += 2*M_PI;
if(min_lon_d>max_lon_d) max_lon_d += 2*M_PI;

a[i]=d[i]=0;

/* test if the orbit crosses the box and the box shifted by +- 2*M_PI */

for(s = -1 ; s <= 1 ; s++)
{
if( (min_lon+s*2*M_PI-min_lon_a)*(max_lon+s*2*M_PI-max_lon_a)<=0)
a[i]=1;
if( (max_lon+s*2*M_PI-min_lon_d)*(min_lon+s*2*M_PI-max_lon_d)<=0 )
d[i]=1;
}

min_lon_a = fold(min_lon_a-INCR);
min_lon_d = fold(min_lon_d-INCR);
max_lon_a = fold(max_lon_a-INCR);
max_lon_d = fold(max_lon_d-INCR);
}

}
/*

```

Function fold

Written by:

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Woods Hole Oceanographic Institution
Woods Hole, MA

Modifications:

None.

Purpose:

To fold an angle to the range $0-2\pi$ by removing or adding an integer number of 2π .

Method:

None.

Usage:

`r = fold(x)`
double r, x

Input:

x angle to be folded, in radians

Output:

None.

Returns:

r folded angle corresponding to x.

Subroutines Required:

`remainder(x,y)` double x,y; which returns a number in the range $-y/2$ to $y/2$ which differs from x by an integer number times y, as defined in the reference.

Reference:

ANSI/IEEE Std 754-1985

```
*/  
double fold(x)  
    double x;  
{  
    double r;  
    r=remainder(x,2*M_PI);  
    return(r<0?r+2*M_PI:r);  
}
```

C Shell Listings

This appendix contains listings and descriptions of shell scripts used in this report. Experienced shell programmers may wish to modify the scripts for complicated analysis. For novice shell programmers, a description of each of the scripts is given along with necessary modifications.

C.1 Repeat Analysis

This shows how to use the basic programs to clean and correct raw GEOSAT GDRs and perform the repeat analysis described in section 6. This particular shell script uses the C-Shell instead of the Bourne Shell ⁴ since the C-Shell provides the command *foreach*. With a few minor modifications, these scripts could perform an analysis on an entire region instead of one orbit. The first script assumes that each file is in a directory named with the cycle number and the filename follows the convention given in section 4.

```
#csh
# shell for generating single orbit repeat
# track analysis
mkdir means
foreach i (c???)
echo $i
#
cat $i/$i."$1" | g-clean1 | g-correct | g-clean2 >! tmp
(cat tmp | g-spike | g-spline 1 22 48 3.3 0.97992165 >
$i/$i."$1"c)
end
#
echo Performing repeat analysis.
g-repeat c*/c*."$1"c > means/mean."$1"c
```

This script is called with the orbit number desired:

```
gs-repeat a002
```

First a directory is created to hold the means. Then a loop is created using all the cycle subdirectories. The desired orbit *a002* is then cleaned, corrected and splined for all available cycles. When all cycles are processed, the repeat analysis is performed and the mean/geoid is placed in the *means* subdirectory.

The second script is similar to the first except that it assumes that each file is in the current directory.

```
#csh
# shell for generating single orbit repeat
# track analysis
foreach i (c???.$1)
echo $i
#
```

⁴There are many good shell programming books available to describe the similarities and differences between the C-Shell and the Bourne Shell.

```

cat $i | g_clean1 | g_correct | g_clean2 >! tmp
(cat tmp | g_spike | g_spline 1 22 48 3.3 0.97992165 >
"$i"c)
end
#
echo Performing repeat analysis.
g_repeat "$i"c > mean."$1"

```

C.2 Data Extraction

Sometimes it is useful to view cleaned and corrected data. The following scripts show how this may be done.

```

#
# shell script for extracting clean sea surface heights
#
cat $1 | g_clean1 | g_correct | g_clean2 | g_spike | g_ext 1
L ha > "$1"h
#

```

This script would remove bad data and extract the latitude, the longitude and the sea surface height.

```

#
# shell script for extracting clean significant wave heights
#
cat $1 | g_clean1 | g_correct | g_clean2 | g_spike | g_ext 1
L w sw > "$1"w
#

```

This script would extract the significant wave height and the standard deviation of the significant wave height.

C.3 Imaging

This script shows how to create a variability image using the output from the repeat script shown above. This script uses the UNIX command *cut* to select the necessary data from the input files. In this example, the latitude, longitude and the variability columns are extracted and piped to *g_image*. The arguments to *g_image* are the minimum and maximum latitude, the minimum and maximum longitude and the number of rows and columns in the output image. This image is in SDPS floating point format and needs to be remapped to a bitmap image. This is done using the program *sdps_ftb* which converts floating point images to byte images. The arguments to *sdps_ftb* specify that the bitmap should be scaled from 0.0 to 0.5 and any values less than 0.0 should be set to 254 and values greater than 0.5 should be set to 255.

```

#
# shell for generating equirectangular image
# of variability.
#
cat mean.a* | cut -f2,3,7 | g_image 22 48 284 316 416 512
> vara.sdpsf
cat vara.sdpsf | sdps_ftb -mxlh 0.0 0.5 254 255 > vara.sdps

```

The following script is only a variation of the previous script. It merely demonstrates how to create an image of the mean sea surface height of all the descending tracks in a region. Since there were no arguments given to *sdps_ftb*, the minimum and maximum are found and used for scaling the output bitmap image.

```

#
# shell for generating equirectangular image
# of mean sea surface height.
#
cat mean.a* | cut -f2,3,6 | g_image 22 48 284 316 416 512
> meand.sdpsf
cat meand.sdpsf | sdps_ftb > meand.sdps

```


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| 16. Abstract (Limit: 200 words) Satellite altimeters provide many opportunities for oceanographers to supplement their research with a valuable new data set. The recent GEOSAT exact repeat mission is the first of several altimetry missions proposed during the next decade. To utilize this new data, a software package was developed at the Woods Hole Oceanographic Institution and the University of Hawaii to facilitate the extraction of useful information from the NODC distributed GEOSAT data tapes. This software package was written with portability and modularity in mind. It should be possible to use this package with little or no modifications on data from future altimeters. The code was written in C and tested on Sun workstations and is oriented toward UNIX operating systems. However, since standard code was used, the programs should port easily to other computer systems. The modularity of the code should enable users to create additional programs. Additional programs designed to handle collocated water vapor corrections are also included for comparison. | | | |
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